UPPER OHIO NAVIGATION STUDY, PA FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, DEPARTMENT OF DEFENSE

TRANSMITTING

THE CORPS' UPPER OHIO NAVIGATION STUDY, PA FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL IMPACT STATEMENT FOR OCTOBER 2014 (REVISED AUGUST 2016), PURSUANT TO 33 U.S.C. 549a; PUBLIC LAW 91–611, SEC. 216; (84 STAT. 1830)

PART 5 OF 6

MAY 22, 2017.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

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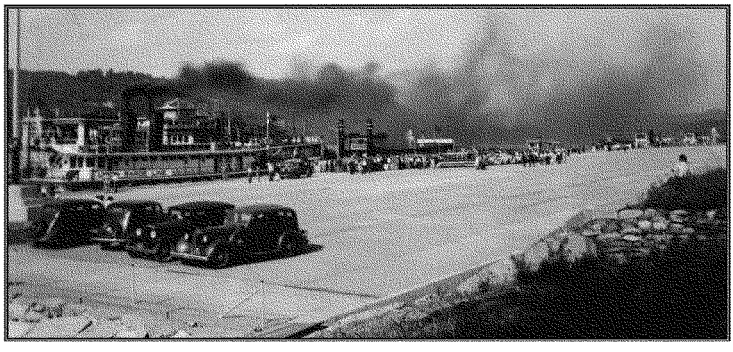
Upper Ohio Navigation Study, Pennsylvania

Volume 5



Opening celebration at Montgomery Locks and Dam - 1936

Emsworth, Dashields, and Montgomery Locks and Dams

RECORD OF DECISION

OHIO RIVER MAINSTEM SYSTEM STUDY
System Investment Plan/Programmatic Environmental Impact Statement
ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

I have reviewed the final integrated System Investment Plan/Programmatic Environmental Impact Statement (SIP/PEIS) for the Ohio River Mainstem System Study (ORMSS), as well as all comments received in response to final agency review. I find the recommended plan addresses the serious structural condition of the locks on this economically vital waterway and is therefore in the public interest. Thus, I approve the plan for use in scheduling future Federal navigation studies and maintenance on the mainstem Ohio River. Further, I approve pursuit of planning and implementation of measures to improve environmental sustainability of the Ohio River.

The basic authority for the ORMSS, is contained in a resolution adopted by the Committee on Public Works of the United States Senate dated 16 May 1955. Further authority was provided through a resolution adopted by the U.S. House of Representatives Committee on Public Works and Transportation adopted 11 March 1982. The ORMSS does not recommend any projects or programs for authorization by Congress. Rather, the primary purpose of the ORMSS is to develop the best System Investment Plan (SIP) for maintaining safe, environmentally sustainable, and reliable navigation on the mainstem Ohio River over a 60-year period from 2010 to 2070. In response to stakeholder input, the study purpose was modified to include identification of high priority needs to improve ecological sustainability and provide a balance between economic and environmental improvements.

The study evaluated the operation and maintenance, rehabilitation, and construction reinvestment needs at the 19 navigation lock and dam sites on the Ohio River Mainstem, with needs determined by the structural condition of each lock and the economic consequence of outages. The ORMSS SIP primarily focused on the long-term needs associated with the locks since the performance of these structures is the principal driver of lock closure. The dams were not part of this study since improvements or modifications to the dams would not alter lock capacity or performance. The magnitude of economic consequences is directly related to the likelihood of a lock outage and the level of waterway traffic. Given uncertainty with regard to future traffic growth, five alternative traffic demand scenarios were developed. These scenarios were based upon three competing outlooks for clean air regulations affecting electric utility output and fuel choices and upon two economic growth outlooks. Risk-based projections of structural condition at each lock throughout its life cycle provided an indication of the likelihood and duration of lock outages due to component failures. Alternative investment options were examined for each lock site within the context of the entire system in order to find the investment option that maximized system benefits net of costs. The SIP/PEIS does

not identify a most likely scenario, nor recommend any of the five system plans; it presents an optimum system investment plan under each scenario.

The final SIP/PEIS recommends the following:

- Increase Operation and Maintenance (O&M) investments to maximize economic efficiency by pursuing the replacement and major rehabilitation of major components when economically justified.

- Complete all authorized navigation improvements as soon as possible at Olmsted, J.T. Myers, McAlpine, Greenup, Lower Monongahela, Kentucky Lock, and Chickamauga.

- Provide optimal funding for the Upper Ohio River Feasibility Study currently underway in order for this project to be included in a WRDA in or around the FY 2012 time frame.

- Initiate main chamber rehabilitation studies as soon as possible for Meldahl, Hannibal, and J.T. Myers.

- Initiate a main chamber rehabilitation study for Pike Island in the near term (before 2015).

- Pursue planning and implementation of measures to improve environmental sustainability in collaboration with other interests.

- Complete the Endangered Species Act, Section 7 consultation process for the Operation and Maintenance of the Ohio River Corps facilities and incorporate all Reasonable and Prudent Measures identified, if any.

- Complete on-going work on the Markland gates as soon as possible.

- Evaluate site-specific impacts for follow on studies and other actions and tier from the ORMSS SIP/PEIS in accordance with the President's Council on Environmental Quality Regulations for Implementing NEPA, 40 C.F.R. 1502.20.

- Implement the recommendations of the Ohio River Basin Comprehensive Study in order to assess water resource opportunities throughout the basin in collaboration with other interests. Planning efforts include identification and evaluation of opportunities to improve environmental sustainability throughout the basin including the tributaries.

- Establish a standalone program (Ohio River Navigation System Investment Program) to update the data and models used in preparing the System Investment Plan. Expand the program capability to include the Ohio River dams and include tributary (Allegheny, Monongahela, Kanawha, Green, Tennessee, and

Cumberland Rivers) locks and dam structures to support navigation investment decisions and manage future system risk. Use these tools in annual budget formulation.

- Use the Ohio River Navigation System Investment Program to reexamine the medium and long term needs identified in the SIP to optimize investments on these projects.

- The System Investment Plan was not developed considering a constrained federal budget or considering the total Ohio River System. Follow on actions need to be conducted to analyze investment strategies with a constrained Federal budget and expanded to include all navigation locks, dams, and channels on the Ohio River and its navigable tributaries.

OHIO RIVER LOCK INVESTMENT ALTERNATIVES

The vast majority of Ohio River locks are between 25 and 50 years of age, whereas by 2015, 40% of Ohio River locks will be over 50 years old. As locks age and their reliability decreases, closures of main chambers for repair become more likely. When these closures occur, smaller auxiliary lock chambers must carry the entire traffic burden. Because these chambers are smaller, tows must be uncoupled and moved through in multiple lockage operations (usually two lockage cuts, up to five at Emsworth, Dashields and Montgomery) rather than a typical single cut lockage operation used at a main chamber.

For navigation investments, the No Action Alternative (Without Project Condition or WOPC) was continuance of a reactive maintenance strategy. Alternatives considered in the final array of With Project Conditions (WPC) for navigation investment consisted of:

- The Advanced Maintenance Alternative (AMA) which allows for scheduled replacement of any critical lock component when economically justified,
- The Major Rehabilitation Alternative (MRA) which allows both component replacement and bundling of component replacements into major rehabilitation packages that meet Corps criteria for that program when economically justified, and
- The Lock Modernization Alternative (LMA) which allows proactive maintenance and major rehabilitations as well as lock modernization (i.e., extension or replacement) options.

Measures eliminated from detailed consideration in the WOPC are in Section 8.4, and the alternative of Federal Disinvestment in the system is in Section 8.6.1 of the SIP/PEIS. Measures eliminated from detailed consideration in the WPC are in SIP/PEIS Sections 9.2.2.3 for maintenance, 9.2.3.3 for operations, and 9.3.5 for modernization.

MEASURES FOR OHIO RIVER ECOSYSTEM SUSTAINABILITY

Significant degradation of aquatic and riparian/floodplain resources have occurred as a result of human activities throughout the Ohio River region. These include, but are not limited to, water pollution from municipalities and industries; acid mine drainage; in-stream extraction of sand and gravel; construction and operation of high-lift locks and dams; loss of shallow water habitat due to maintenance of the navigation channel; disruptions to mussel beds due to barge fleeting areas, tow queuing, disposal of dredged materials, and conversion of habitat for agriculture, residential, commercial, and industrial uses. Habitat conversions are expected to continue in the future as development in or adjacent to the river continues to occur.

A total of 26 high priority ecosystem sustainability measures were identified through an Expert Elicitation Process and were considered in Section 9.4 of the SIP/PEIS. The No Action Alternative included 14 types of measures that could be implemented through a variety of existing Corps authorities, such as the Ohio River Ecosystem Restoration Program, the Ohio River Basin Comprehensive Study, and Water Resources Development Acts Sections 206 and 1135, especially in collaboration with other agencies and interests including non-Federal sponsors, as appropriate. The two ecosystem sustainability alternatives in the WPC were the Moderate and Maximum Ecosystem Sustainability Plans. These were developed based on approximate costs, need for modified or additional authority, complexity, and several scientific, policy, funding, and timing uncertainties. The Moderate Plan includes five specific types of measures in addition to the 14 from the WOPC, while the Maximum Plan consisted of all 26 measures identified.

RECOMMENDED PLAN

The recommended plan for navigation investment is the LMA. This plan includes component replacements as in the AMA as well as bundling of component replacements as in the MRA, when and where these are economically justified. It also provides for lock replacements or extensions where needed and justified. The LMA includes elements of the No Action Alternative in those instances where a reactive maintenance strategy is the best solution. Individual measures, as well as the mixture of actions, are optimized to provide the greatest benefit from Federal investment. The LMA is the National Economic Development (NED) Plan. The LMA is also the Environmentally Preferred Alternative because it provides the greatest reduction in total transit days on the Ohio River mainstem. Reducing total transit days translates into substantially less time that tows are in queue in environmentally sensitive tailwater areas. Tailwaters downstream of locks and dams on the Ohio River provide habitats that most resemble pre-impoundment riverine conditions important to numerous species of fish, mussels, and other aquatic life.

The recommended plan for ecosystem sustainability is the Moderate Plan. This plan includes all elements of the No Action plan and adds five other types of measures to improve ecosystem sustainability. While the Maximum Plan would be environmentally preferable to either No Action or the Moderate Plan, uncertainties surrounding individual

restoration project implementation or program development identified in the Maximum Plan led to recommendation of the Moderate Plan. As opportunities arise, especially during planning for site-specific navigation improvements, however, individual measures contained in the Maximum Plan will be pursued in conjunction with non-Federal sponsors.

PUBLIC/AGENCY COMMENTS IN THE FINAL SIP/PEIS

The public/agency comment for the final SIP/PEIS was open from February 25, 2011 to March 28, 2011. The comment period was extended an additional 15 days to accommodate a request from a commenter to provide additional time to review the document. A total of 49 comments were received during the review period. A summary of the specific comments is attached to this Record of Decision (ROD). Seven groups, representing Federal and state agencies and non-governmental environmental organizations, provided comments. Commenter's included the U.S. Environmental Protection Agency (EPA), Indiana Department of Natural Resources, the Kentucky Department of Environmental Protection, the Kentucky Resources Council, the Ohio River Foundation, Oxbow Inc., and The Nature Conservancy. Many of the comments from the non-governmental organizations were either recommendations or were identical to comments provided for the initial public review conducted in 2006, which had been previously addressed. Other comments provided by the NGOs were addressed in the report. Some technical comments provided by The Nature Conservancy provided new information on natural resources and were incorporated into the report. Comments from resource agencies were generally supportive, questioned some of the methodologies utilized in the ORMSS analyses, or provided specific recommendations for future studies and language for the ROD. Comments provided during the final public review did not affect study analyses or conclusions and consequently warranted no major revisions to the ORMSS SIP/PEIS.

COMMITMENTS

Foremost of commitments toward mitigating systemic environmental impacts is adoption of sustainability-focused mitigation measures for future actions. Sustainability-focused mitigation differs from traditional replacement-in-kind mitigation in that it includes measures directed toward those high priority ecosystem needs identified through the Expert Elicitation Process. In addition, to address systemic issues related to the navigation system, the Corps will incorporate the following environmental components into future site-specific studies:

- Evaluation, and if feasible construction, of native fish passage strategies at each lock and dam along the Mainstem during studies for lock modernization and major rehabilitation. These strategies will be developed to benefit not only native fish populations but other valued aquatic ecosystem components such as freshwater mussels.

- Continuance and expansion, as needed, of the Interagency Working Group to participate in and to review and comment on studies as they progress.

- Identification, description, and quantification of riverine habitat within the individual project's area of influence.

- Incorporation of sustainability planning within each individual project's area of influence.

- Development of a National Environmental Restoration (NER) Plan that will become part of the Combined NED/NER Plan for authorization of each site-specific project if all policy conditions are met. All separable ecosystem restoration costs, including feasibility study costs, will require a non-Federal cost sharing partner in accordance legislation and policies of the time.

Although the selected plans do not include specific recommendations for monitoring of mitigation commitments, it will be necessary for the Corps of Engineers, in cooperation with stakeholders (i.e., Federal, State, and local agencies, along with non-governmental entities) to maintain awareness and communication of economic and ecological conditions and issues in order to make necessary adjustments to the selected plans.

It is my decision that the LMA for Federal navigation investment and the Moderate Plan for ecosystem sustainability will be pursued. These plans as detailed in the ORMSS SIP/PEIS include sufficient flexibility for revision and update as conditions indicate the necessity to do so. The public interest will best be served by implementing these plans for improving and balancing economic and environmental sustainability of the Ohio River mainstem. Thus, I approve the Lock Modernization and the Moderate Ecosystem Sustainability Plans for the Corps of Engineers to use in planning and budgeting Federal investments in and along the mainstem Ohio River.

JOHN W. PEABODY
Major General, U.S. Army
Division Engineer

8 July, 2011
DATE

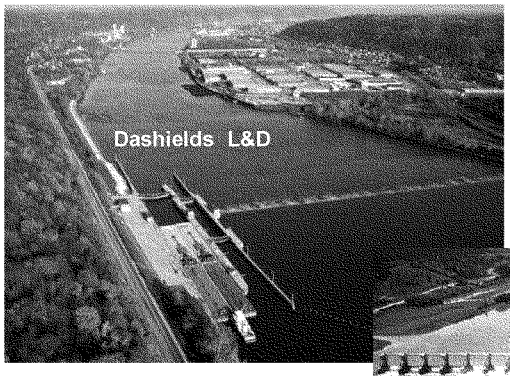
US Army Corps
of Engineers
Great Lakes and Ohio River Division
LOUISVILLE DISTRICT / HUNTINGTON DISTRICT / PITTSBURGH DISTRICT

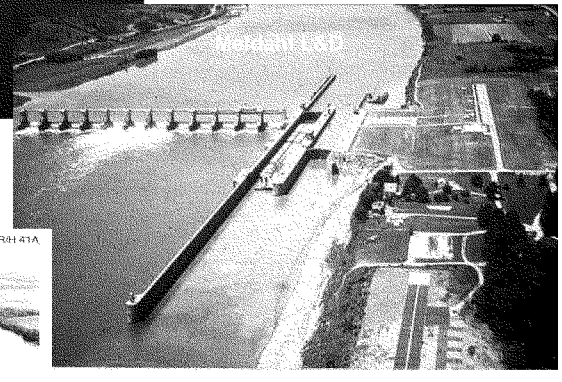
Ohio River Mainstem Systems Study (ORMSS)

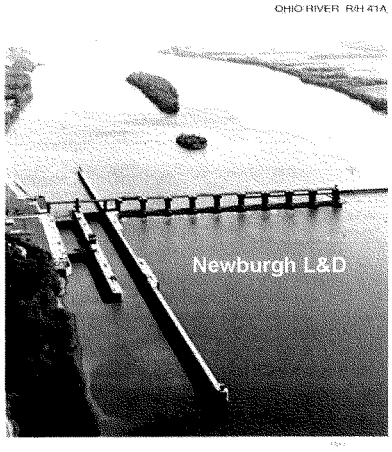
System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Integrated Main Report







July 2011

US ARMY CORPS OF ENGINEERS, GREAT LAKES AND
OHIO RIVER DIVISION
OHIO RIVER MAINSTEM SYSTEM STUDY
INTEGRATED SYSTEM INVESTMENT PLAN AND
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
JULY 2011
Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Kentucky

Abstract: The primary purpose of the Ohio River Mainstem System Study (ORMSS) was to develop the best System Investment Plan (SIP) for maintaining safe, environmentally sustainable, and reliable navigation on the 981 mile long Ohio River over the period 2010-2070. The SIP is intended to serve as a long term planning tool for decision makers in the budgeting and asset/infrastructure management process and does not recommend any specific projects for authorization or construction. This study evaluated system-wide impacts through a Programmatic Environmental Impact Statement (PEIS). Navigation investment alternatives were formulated based on five possible scenarios associated with utility coal, air quality compliance policy, and economic growth. Navigation infrastructure recommendations in the SIP serve to reduce expected maintenance and repair costs and associated delays to navigation due to lock closures. The SIP includes a mix of investments ranging from reactive maintenance (replacement of lock components as failure occurs) to advance maintenance (replacement of lock components before failure) to major rehabilitations (bundling of multiple component replacements into a rehabilitation) to lock modernization on the upper Ohio River. Recommendations for new lock construction will require justification through follow-on detailed feasibility study. Identification of measures to improve ecological sustainability was included as a study purpose to provide a balance between economic and ecological development. Recommendations for ecosystem sustainability alternatives were formulated from measures identified during facilitated group discussions that focused on highest priority needs to enhance aquatic and riparian ecosystem sustainability. Ecosystem related recommendations included measures to improve ecosystem sustainability in collaboration with other interests. A major focus of the PEIS was the comprehensive Cumulative Effects Assessment (CEA) that evaluated impacts from past, present, and reasonably foreseeable future actions on ten categories of Valued Environmental Components. For many of the recommended actions, future site-specific studies will be required prior to project approval or recommendation for authorization.

This document is an integrated report wherein the PEIS is embedded within the planning report. Table 2-2 in Section 2 identities locations of discussions required to be included in the PEIS.

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
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P.O. BOX 59
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System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Integrated Main Report

July 2011

Ohio River Mainstem System Study Integrated Main Report
(Programmatic Environmental Impact Statement Included)

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LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

AES —Analysis of Environmental Sustainability

AM - Adaptive Management

AMD - Acid Mine Drainage

AR - Advanced Replacement of Lock Component(s)

ARA - Advanced Replacement Alternative

AWO - American Waterways Operators

BCERE - Baseline Cost Estimate for Real Estate

BEA —Bureau of Economic Analysis

BOD - Biological Oxygen Demand

BMP - Best Management Practices

CE - Cumulative Effect

CEA - Cumulative Effects Assessment

CEQ - President's Council on Environmental Quality

CG - Construction General Funding Account

CO Carbon Monoxide

CS - Clear Skies

CSO - Combined Sewer Overflows

CSw/o Hg - Clear Skies without Mercury Limits

CWA Clean Water Act

DINAMO - The Association for Development of Inland Navigation in America's Ohio Valley

DO - Dissolved Oxygen

LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

EDM — Emsworth, Dashields, and Montgomery Locks and Dams

EIS — Environmental Impact Statement

EJ — Environmental Justice

EmSh — Emerald Shiner

ENGO — Environmental Non-Governmental Organization

ERDC — U.S. Army Corps of Engineers Research and Development Center

EO — Executive Order

EOP — Environmental Operating Principles

EP — Engineer Pamphlet

ER — Engineer Regulation

ERNS — Emergency Response Notification System

ERP — Ohio River Ecosystem Restoration Program

ES — Environmental Sustainability

FAF - U.S. Department of Transportation's Freight Analysis Framework

FONSI — Finding of No Significant Impact

GSA — General Service Administration

H&S — Health and Safety

HQUSACE — U.S. Army Corps of Engineers Headquarters

HSI — Habitat Suitability Indices

HU — Habitat Unit

IAIA — International Association for Impact Assessment

LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

ITR — Independent Technical Review

IWG — Interagency Working Group

JTU — Jackson Turbidity Unit

L/D — Locks and Dams or Lock and Dam

LM — Lock Modernization

LMA— Lock Modernization Alternative

LPMS — Lock Performance Monitoring System

LRD — Great Lakes and Ohio River Division

LRN — U.S. Army Engineer Nashville District

m^2 — square meters

MIwb — Modified Index of Well Being

MGQCS — Miter Gate Quick Changeout System

MR — Major Rehabilitation

MRA — Major Rehabilitation Alternative

MRER — Major Rehabilitation Evaluation Report

MS — Marginally Sustainable

MSA — Metropolitan Statistical Area

NAAQS — National Ambient Air Quality Standards

NAVPAT — Navigation Predictive Analysis Technique

NED — National Economic Development

NEPA — National Environmental Policy Act of 1969

LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

NES — National Environmental Sustainability Plan

NGO — Non-Governmental Organizations

NHL — National Historic Landmarks

NOx — Nitrous Oxides

NPDES - National Pollutant Discharge Elimination System

NR — National Register of Historic Places

NRC — National Research Council of the National Academy of Sciences

NS — Not Sustainable

NSP — Navigation Stewardship Program

NTU — Nephalometric Turbidity Unit

NGO — Non-Governmental Organizations

03 — Ozone

O&M — Operations and Maintenance

ODNR — Ohio Department of Natural Resources

OHDW — Ohio Department of Natural Resources, Division of Watercrafl

ORFIn — Ohio River Fish Index

ORThJWR - Ohio River Islands National Wildlife Refuge

ORNIM — Ohio River Navigation Investment Model

ORS — Ohio River Navigation System

ORSANCO — Ohio River Valley Sanitation Commission

ORV — Ohio River Valley

LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

OSB — Oversight Board

OSU - Ohio State University

P&G - Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies

PCBs — Polychlorinated Biphenyls

PDT — Product Delivery Team

PED — Preconstruction Engineering and Design

PEIS — Programmatic Environmental Impact Statement

PGN — Planning Guidance Notebook

pH - A measure of acidity and/or alkalinity

PM - Particulate Matter

QC — Quality Control

RCRA — Resource Conservation and Recovery Act

REDM — Real Estate Design Memorandum

REP - Real Estate Plan

RFFA — Reasonably Foreseeable Future Action

RFR — RiparianlFloodplain Resources

rm — River Mile

RM — Reactive Maintenance

RMA — Reactive Maintenance Alternative

ROD — Record of Decision

SHPO — State Historic Preservation Officer

LIST OF ACRONYMS
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

SIP — System Investment Plan

SO_2— Sulfur Dioxide

TES — Threatened and Endangered Species

TMDL — Total Maximum Daily Load

TSS — Total Suspended Solids

UB — Utility Based

UBH — Utility Based High

ug/L — Micrograms per Liter

USACE — U.S. Army Corps of Engineers

USEPA — U.S. Environmental Protection Agency

USFWS — U.S. Fish and Wildlife Service

USGS — U.S. Geological Survey

UMR/IWW — Upper Mississippi River/Illinois Waterway

VEC — Valued Environmental Component

VOC — Volatile Organic Compound

WOPC — Without Project Condition

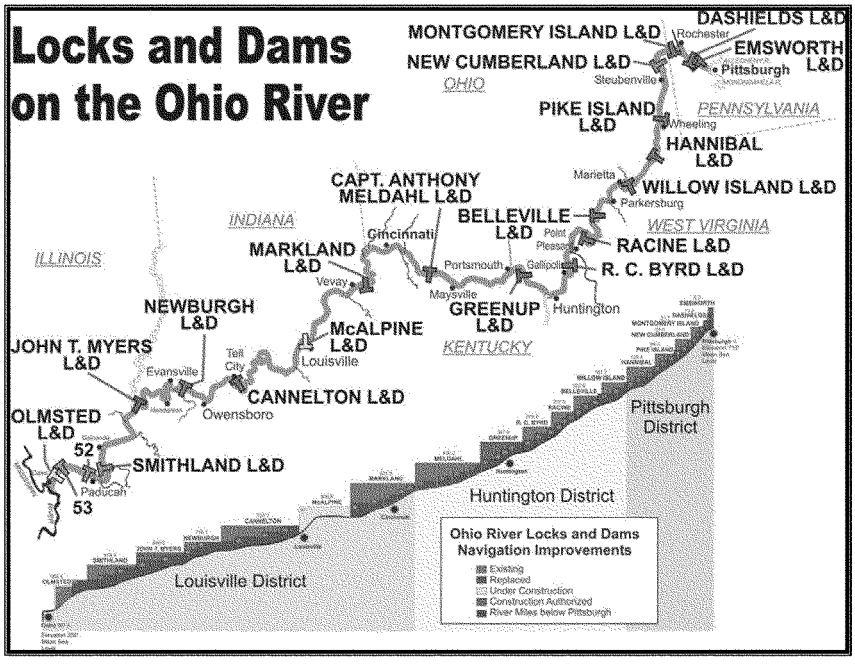
WPC — With Project Condition

EXECUTIVE SUMMARY

1. Valuing Navigation on the Ohio River System.

The Ohio River Mainstem is the principal artery of the Ohio River System (ORS), which also includes the navigable tributaries Allegheny, Monongahela, Kanawha, Big Sandy, Kentucky, Green, Tennessee and Cumberland rivers. Users of the Ohio River System ship by barge 270 million tons of commodities worth over $30 billion, saving over $2 billion in transportation costs annually. These savings result in additional national output estimated at over $11 billion, which makes possible approximately 100,000 jobs and $3 billion in income.[1]

Figure 1
Ohio River Mainstem Plan and Profile



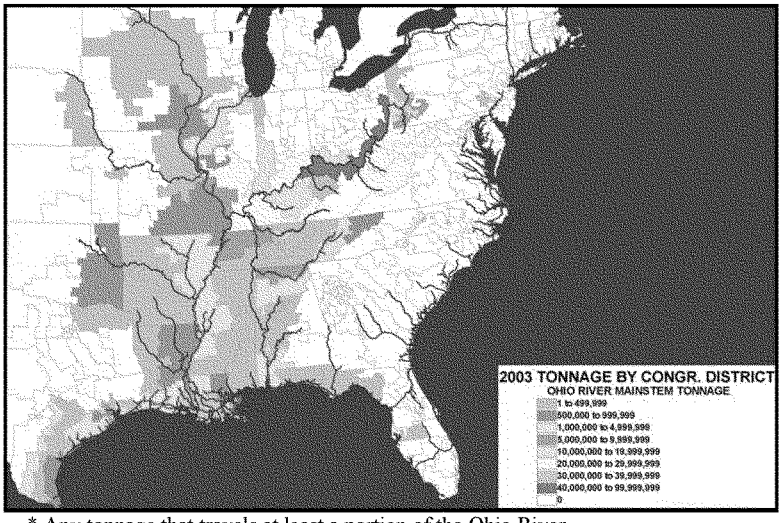
The Ohio River Basin (ORB) is rich in natural resources and is home to over 31.5 million people. There are 57 coal-fired power plants in the ORS that provide 20 percent of

[1] *Regional Economic Development Impacts on the Ohio River Basin due to Commodity Savings Along the Ohio River System*, September 1999, Marianne Matheny, USACE-NAB and Dennis Robinson, USACE-IWR

the nation's coal-fired electric generation capacity. One of the primary reasons the electricity rates in the region are among the lowest in the nation is the relatively inexpensive transportation costs to deliver coal to the power plants via the waterway. Per weight of commodity, coal accounts for 50-60% of the ORS waterway shipments.

The Ohio River is a major transportation artery that serves as an alternative to increasingly congested highways and rail lines for the movement of domestic cargo. Figure 2 shows the extent to which Ohio River mainstem traffic is distributed throughout the eastern United States.

Figure 2
Distribution of Ohio River Traffic*



* Any tonnage that travels at least a portion of the Ohio River.

A significant portion of Ohio River mainstem tonnage passes through Gulf ports in route to/from foreign markets. The value of the Ohio River to communities and industry is transparent during normal operation. However, when lock closures occur, traffic can be slowed or even stopped, affecting the delivery of goods and ultimately increasing costs to consumers. Recent unscheduled closures at Greenup, McAlpine, Hannibal and Montgomery locks have cost millions of dollars in additional transportation costs alone. Table 1 shows data related to these closures. The economic impacts reported in this table reflect only the delay costs imposed on tows waiting to use the lock. Several investigations following these main chamber lock closures found there are other logistical costs associated with closures that can be quite high. For example, a survey of Greenup Lock users uncovered $29 million in costs above and beyond the $13.2 million in delay costs shown in Table 1. In the present business environment of just-in-time delivery of goods and commodities, any closure interrupts production, forces movements onto other transportation modes, and increases costs which are then passed along to the consumer.

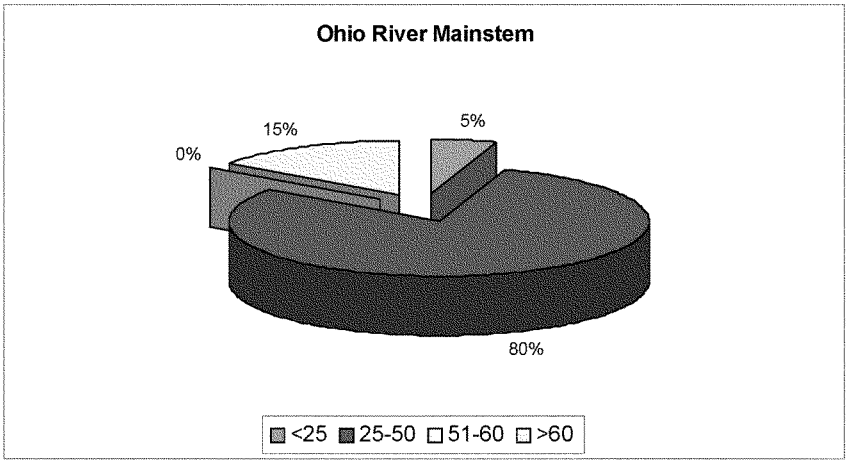
Table 1
Ohio River Mainstem Lock Closures 2002-2005

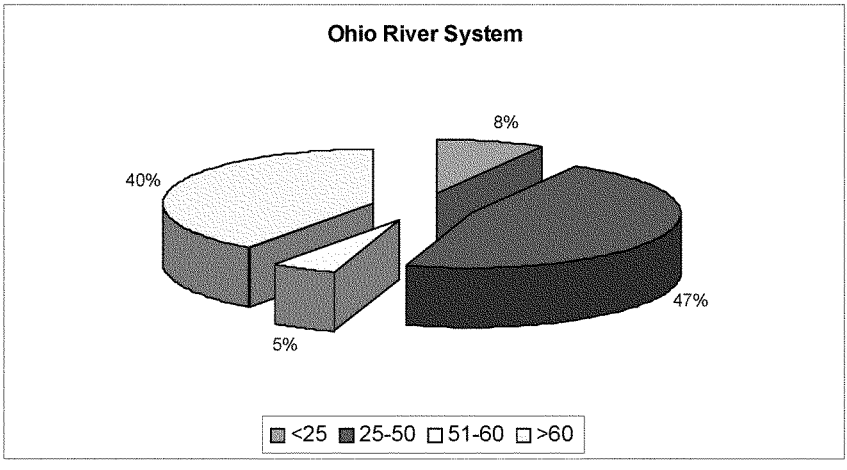
Lock	Closure Dates	Closure Duration	Delay (hrs) Max	Delay (hrs) Avg	Number of Tows Delayed	Delay Costs $
Hannibal	Nov 1 - 15, 2005	15 days	140	58	125	$ 3,000,000
McAlpine	Aug 8 - 19, 2004	10 days 23.4 hrs	257	77	19	$ 695,000
Greenup	Sep 8 - Oct 31, 2003	52 days, 8 hrs	93	38	718	$ 13,200,000
Montgomery	Jun 18 - 28, 2002	10 days, 17 hrs	110	34	130	$ 1,200,000
Montgomery	Jul 15 - 31, 2002	16 days, 16 hrs	132	33	179	$ 1,700,000

Source: Lock Performance Monitoring System (LPMS) and Institute for Water Resources (IWR) cost data.

The lock closures cited above are symptomatic of an aging infrastructure and projects with small auxiliary lock chambers. As locks reach the limits of their design life, closures of main chambers for repair become more likely. When these closures occur, smaller auxiliary lock chambers must carry the entire traffic burden. Because these chambers are smaller, tows must be uncoupled and moved through in multiple lockage operations (usually two lockage cuts) rather than a typical single cut lockage operation used at a main chamber. The multiple cut lockages take nearly three times as long, and at many lock projects this additional time leads to the lengthy delays shown in Table 1. The age distribution of the mainstem locks is shown in Figure 3. Figure 3 also shows that the vast majority of Ohio River locks are between 25 and 50 years of age, with 15% of locks being greater than 50 years of age. For the system as a whole, nearly half of the locks are between 25 and 50 years of age, and another 45% are over 50 years old, indicating that the problem of aging infrastructure is even more acute on the Ohio River's navigable tributaries. By 2015 locks over 50 years of age represent 40% of Ohio River locks and 68% of Ohio River System locks.

Figure 3
Age Distribution
Ohio River Mainstem and Ohio River System Main Lock Chambers





2. Study Purpose.

The primary purpose of the Ohio River Mainstem Systems Study (ORMSS) is to develop the best System Investment Plan (SIP) for maintaining safe, environmentally sustainable, and reliable navigation on the Ohio River over a 60-year period from 2010 to 2070. The study evaluated the operation and maintenance, rehabilitation, and construction reinvestment needs at the 19 navigation lock and dam sites on the Ohio River Mainstem as shown in Figure 1.[3] The study presents five individual plans for meeting the system needs based on five different traffic forecast scenarios. Reliable operation of these structures is critical to future commercial navigation throughout the Ohio River basin. In response to stakeholder input, the study purpose was modified to include the identification of measures to improve ecological sustainability to provide a balance between economic and environmental improvements.

3. Study Processes.

The ORMSS report is an integrated System Investment Plan (SIP) and Programmatic Environmental Impact Statement (PEIS). The PEIS is centered on a system-wide Cumulative Effects Assessment (CEA) and other studies that focused on specific issues identified through the study scoping process. The study team sought to determine effects on the sustainability of Ohio River resources from all past, present and reasonably foreseeable future activities on the river, not just those associated with navigation improvements. An Interagency Working Group (IWG) consisting of federal and state natural resource agencies and non-governmental environmental interests was involved in the development of the CEA and the PEIS.

Early in the Ohio River Mainstem Systems Study two site specific lock facilities were identified where initiation of construction was warranted prior to the completion of the System Investment Plan (SIP). These two high traffic projects, J.T. Myers and Greenup Locks and Dams, demonstrated immediate, economically justified investment opportunities during early prioritization work. Utilizing the same rigorous engineering risk and reliability-based approach used in this study, feasibility-level documentation and full NEPA analysis were produced for these 'near-term' sites: J.T. Myers and Greenup Locks and Dams. These projects were authorized by the Water Resource Development Act (WRDA) 2000 Sections 101(a) (14) and (15), respectively. In addition, the IWG worked together to develop the Ohio River Ecosystem Restoration Program which was also authorized in WRDA 2000. However, the Ohio River Ecosystem Restoration Program has yet to receive Congressional appropriations for implementation. As such, the program is now on the candidate list for de-authorization. Therefore, it is still mentioned in the final SIP/PEIS, although it is not included as a reasonably foreseeable future action in either the Without- or With-Project Conditions. Though not necessarily a part of the Ecosystem Restoration Program, an assessment of high priority needs to enhance ecological sustainability is included in the current report.

[3] Olmsted L/D will replace L/Ds 52 and 53 when completed.

The study has benefited by the lessons learned in the Upper Mississippi River-Illinois Waterway Navigation Feasibility Study. A number of issues identified by the National Academy of Science review of that study influenced the direction of ORMSS:

- Benefits were estimated on a system basis, rather than one lock at a time.
- Nonstructural alternatives, like traffic scheduling, were evaluated.
- The Ohio River Navigation Investment Model, was developed to fully integrate economic and engineering data..
- Modifications were made to the ORNIM model to produce input data for the Navigation Predictive Analysis Technique (NAVPAT) model, thus integrating environmental and other analyses.
- The cumulative effects analysis incorporated all actions producing impacts to Ohio River resources.
- A range of scenarios based on plausible futures was developed to account for the uncertainty inherent in forecasting traffic.
- The Waterway Analysis Model (WAM), a component of ORNIM, used simulation modeling techniques to estimate throughput capacity.
- A risk and reliability assessment model was developed for analyzing lock structures.

A variety of stakeholders participated in the development of the study through forums as varied as public meetings and workshops with industry groups, environmental groups, and academia. The ORMSS study team has solicited input and shared work with all interested stakeholders through various communication channels.

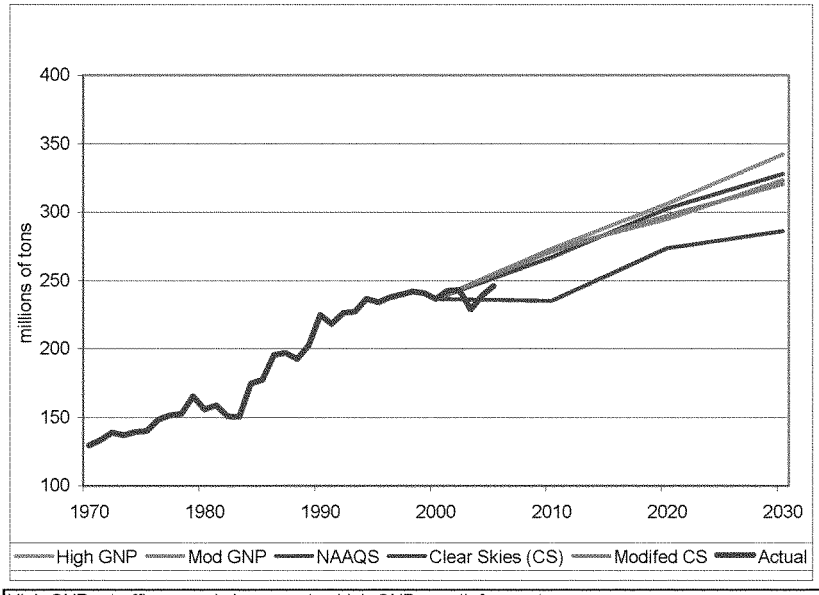
Independent technical review of all of the analyses has been conducted by subject matter experts. The independent technical review of the economics was completed entirely by experts external to the Corps and included two members of the National Academies of Science who specifically looked at traffic forecasts and the Ohio River Navigation Investment Model. Whether these experts were from academia, other agencies, or within the Corps, their reviews have provided authenticity and veracity to the conclusions and recommendations contained herein. An In-Progress Review was also conducted in February 2004 with Corps Headquarters, providing an opportunity to make mid-course adjustments of the study.

4. Risk and Reliability.

The major variables in developing a system investment plan for the mainstem locks are lock condition and traffic demand. Forecasts of both variables are uncertain giving rise to the need for a risk based analysis to insure that the study conclusions and recommendations cover the plausible range of future scenarios. Engineering reliability models were used to analyze lock component reliability and capture the uncertainty of lock performance while accommodating forecasted traffic demand. Multiple traffic forecasts were used to model river traffic. Five forecasts were developed for the study, each recognizing that the primary driver of river traffic is utility coal at 50-60% of system tonnage transported (see Figure 4). Traffic forecasts used in this study indicate that demand for Ohio River navigation is projected to grow between 0.51-1.06 percent annually, depending on the forecast scenario. Forecasted growth is confirmed by recent

announcements made regarding clean-coal technology plants, expansions to coal-fired power plants, and coal gasification plants in the basin.

Figure 4
Ohio River Historic and Forecast Traffic, 1970 - 2030



High GNP -- traffic scenario incorporates high GNP growth forecasts .
Mod GNP -- traffic scenario incorporates moderate GNP growth forecasts.
NAAQS -- traffic scenario incorporates US EPA National Ambient Air Quality Standards.
Clear Skies -- traffic scenario incorporates Bush Administration proposals for emission reductions from electric power plants.
Mod CS -- traffic scenario incorporates all aspects of Bush Administration proposals for emission reductions, excepting proposals regarding Mercury.

The ORMSS process included development of a state-of-the-art analytical model that incorporated the uncertainty of traffic forecasts and the reliability of lock components into a procedure to optimize reinvestment strategies. The Ohio River Navigation Investment Model (ORNIM) used in this analysis determined system-wide benefits and costs of different reinvestment alternatives through the integration of engineering and economic inputs. ORNIM output in the form of traffic forecasts were used as input to the NAVPAT model. ORNIM is able to evaluate tradeoffs among alternatives over time to optimize maintenance, rehabilitation and construction needs.

5. Formulation and Evaluation.

a. Without Project Condition (WOPC). The without-project condition is the most likely condition expected to exist in the future in the absence of implementation of water resource project investment alternative(s). The future without-project condition constitutes the benchmark against which action alternative plans are evaluated. For this study, the WOPC was formulated as the least Federal cost plan providing viable navigation on the Ohio River Mainstem. The WOPC as developed is a reactive maintenance strategy for major lock components. This assumes that as a component fails, it is repaired in a timely fashion; however, no proactive maintenance is performed, i.e., components are not repaired or replaced in anticipation of failure.

Performance of the system's aging infrastructure will continue to deteriorate in the future without aggressive maintenance or lock modernization. The three upper-most projects on the Ohio River (Emsworth, Dashields, and Montgomery (EDM)) range in age from 70 to 85 years, well beyond original design life. There are two major concerns with the physical condition of the lock walls at EDM: 1) concrete deterioration below concrete overlays placed during rehabilitations in the 1980s, and 2) questionable remaining effectiveness of metal anchors installed during those rehabilitations to make these walls stable. These problems contributed to predictions of very high future maintenance costs at EDM in the WOPC.

Physical conditions lead to lock closures. When these closures affect the main lock chamber, traffic through the project must use the smaller auxiliary lock chamber. In the case of projects with 1200' main chambers and 600' auxiliary chambers this means it will take tows two lockage operations to transit the project, and in the case of EDM with their 600' main chamber and 360' auxiliary chambers it will take tows five cuts with tow sizes limited to five rather than the typical 15 barges. All of this means additional time and operating costs to process through the lock. Where traffic exceeds the ability of the auxiliary to process traffic, tows will experience significant delays and incur additional operating costs above and beyond the additional time it takes to process a tow through the auxiliary. So both projections of the future physical reliability of the project and projections of future traffic demands will affect future lock performance. Consistent with Corps guidance, the WOPC also includes the timely completion of authorized improvement projects on the entire Ohio River Navigation System (Olmsted, Greenup, Myers, Marmet, Kentucky, Lower Monongahela, and Chickamauga Locks).

1). Economic Analysis of the WOPC. The Ohio River mainstem offers many economic benefits to the region, including: recreation, tourism, water supply for municipal and industrial purposes, hydropower generation, and transportation. The economic analysis completed for the Ohio River Mainstem System Investment Plan focused solely on transportation benefits. These benefits, or transportation savings, are initially measured by comparing the existing waterway transportation costs versus the least cost alternative overland transportation cost, savings that reflect an historically reliable system. A major problem identified in this study is that without investment in the system, aging infrastructure can be expected to be out of service more frequently and for longer durations of time, eroding the per ton transportation benefits realized today. Garnering these benefits comes at a cost, primarily in terms of operations and maintenance costs in the WOPC.

Table 2 summarizes average annual benefits and costs for the WOPC. Net benefits range from $2.15 to $2.36 billion.

Table 2
WOPC Average Annual System Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Total System Benefits	$2,252.8	$2,373.7	$2,351.8	$2,428.7	$2,460.1
Total System Costs	$99.0	$100.1	$100.0	$99.8	$100.1
Net System Benefit	$2,153.8	$2,273.6	$2,251.8	$2,328.9	$2,360.1

2). Environmental Sustainability in the WOPC. The WOPC is also the No-Action alternative under NEPA for navigation improvements. Looking into the future, all Valued Environmental Components (VECs) are fully sustainable except for mussels and riparian/floodplain resources. In the future the mussels and riparian/floodplain resources will remain marginally sustainable. Significant effects to these two categories have occurred from a number of activities which occur not only along the river but also along the basin's tributaries. These activities include, but are not limited to, water pollution from municipalities and industries; acid mine drainage; instream extraction of sand and gravel; construction and operation of high-lift locks and dams; disruptions to mussel beds due to barge fleeting areas, queuing, disposal of dredged materials, and conversion of habitat for agriculture, residential, commercial, and industrial uses. Habitat conversions are expected to continue in the future as development in or adjacent to the river continues to occur.

Initially, the WOPC for ecosystem sustainability assumes full implementation of the as yet unfunded Ohio River Ecosystem Restoration Program and 14 specific types of measures[3] that were determined to contribute to improving long-term sustainability of aquatic and riparian ecological resources. These are collectively referred to as the "Minimal" alternative. Several of these 14 measures deal with specific types of habitat (e.g., islands, mussel habitat, etc.) and can be described as protecting and improving habitats, increasing diversity and connectivity of habitats, restoring populations of native species, and reducing invasive exotic species. These measures could be implemented through a variety of existing Corps authorities, such as the Ohio River Ecosystem Restoration Program, the Ohio River Basin Comprehensive Study, and Sections 206 and 1135, especially in collaboration with other agencies and interests. While some opportunities among the 14 are relatively low-cost and straightforward, others would require additional planning and/or construction. However, the Ohio River Ecosystem Restoration Program has yet to receive Congressional appropriations for implementation. As such, the program is now on the candidate list for de-authorization. Therefore, it is still

[3] See Table 8-10 for a list of environmental sustainability measures in the WOPC ES Plan.

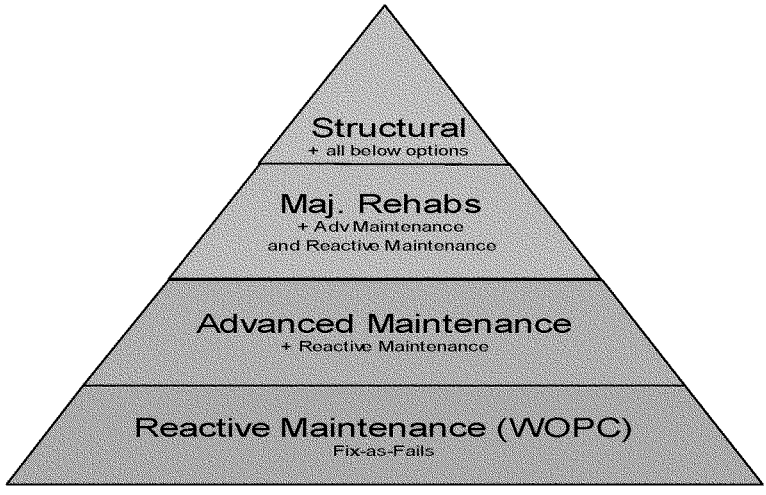
mentioned in the final SIP/PEIS, although it is not included as a reasonably foreseeable future action in either the Without or With Project Conditions.

The Corps operation and maintenance of the navigation system are currently being examined through consultation with the US Fish and Wildlife Service under Section 7 of the Endangered Species Act. In consultation with the US Fish and Wildlife Service, the Corps will develop and implement Reasonable and Prudent Measures being identified through this Endangered Species Act Section 7 consultation. These operational measures along with the various restoration authorities (other than the Ohio River Ecosystem Restoration Program) available to the Corps will help to improve sustainability.

b. With-Project Condition (WPC). The with-project condition is the plan that best addresses the stated planning objectives and addresses the problems and opportunities. The planning objectives were: Ensuring Future Navigability, Improving Navigation Efficiency, and Enhancing Environmental Sustainability. To achieve these objectives, the study team developed a process of formulating and evaluating increasingly intensive alternative actions from proactive maintenance and small scale improvements to large-scale construction reinvestments for navigation improvements. The increasing scale of activities is illustrated in **Figure 5**. Similarly, ecosystem sustainability alternatives in the WPC are described as Moderate and Maximum Plans based on progressive levels of implementation complexity.

Figure 5

Progression of Alternatives in Formulation Process



Proactive maintenance occurs when lock components are replaced or a lock is rehabilitated in advance of component(s) failure. Small-scale improvements considered include floating buoys, permanent mooring cells near lock approach points, and other

infrastructure or procedural opportunities.[4] Large-scale reinvestments evaluated include chamber rehabilitations, construction of new larger lock chambers, and 600' extensions of some auxiliary lock chambers. The key to determining whether an activity should be added to the WPC is if its expected annual benefits exceed its expected annual costs. After all incrementally justified activities are added, the WPC is complete.

Three alternatives involving proactive maintenance and new lock construction were formulated for the WPC analysis and evaluated relative to the reactive maintenance WOPC. Two involved adding more proactive maintenance options. The first, called the Advanced Maintenance Alternative (AMA), allows for scheduled replacement of any critical lock component when economically justified. The second, termed the Major Rehabilitation Alternative (MRA), allows both component replacement and the bundling of component replacements into major rehabilitation packages that meet Corps criteria for that program, again when economically justified. A third alternative, termed the Lock Modernization Alternative (LMA), allows proactive maintenance as well as lock modernization options. Specific lock modernization options considered included 600' extensions of 600'x110' auxiliary chambers and new 600'x110' or 1200'x110' chambers to replace the undersized 360'x56' auxiliaries at Emsworth, Dashields, and Montgomery (EDM). The major elements of the WPC plans that maximize system net incremental benefits for each traffic scenario are shown in Table 3.

Two ecosystem sustainability alternatives were formulated for the WPC analysis to address long-term sustainability of aquatic and riparian ecological resources. The Moderate and Maximum Ecosystem Sustainability Related plans were developed based on approximate costs, need for modified or additional authority, complexity, and several scientific, policy, funding and timing uncertainties of various measures. A total of 26 ecosystem sustainability measures were evaluated; 12 specific types of measures in addition to the 14 from the WOPC. The Moderate plan included 19 of the measures and the Maximum Plan consists of all 26 measures[5]. Existing restoration authorities and operational measures such as the Reasonable and Prudent Measures (being developed through the Endangered Species Act Section 7 consultation) are also carried through into the WPC.

The results of the economic evaluation are quite robust with regard to traffic scenarios; for the most part, the type of investment, whether replacement of a major component of the lock (component replacement - CR), major rehabilitation (MR), or new construction, is unchanged across scenarios and the timing of the investment shows only modest adjustment.

[4] *Small Capital Improvements Study Mooring Facilities*, May 1998, USACE.
[5] The Moderate and Maximum Ecosystem Sustainability Related Plans are described in Table 8-10 of this report.

Table 3.
WPC System Investment Plans for Each Traffic Scenario

Project	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Belleville	CR	MR - 2017	MR - 2017	MR - 2017	MR - 2028
Cannelton	MR - 2017	MR - 2017	MR - 2016	MR - 2017	MR - 2017
Dashields	New 600' - 2011	New 600' - 2010	New 600' - 2010	New 600' - 2010	New 600' - 2010
Emsworth	New 600' - 2010	New 600' - 2010	New 600' - 2010	New 600' - 2010	New 600' - 2010
Hannibal	MR - 2012	MR - 2011	MR - 2011	MR - 2012	MR - 2011
Markland	CR	MR - 2010	MR - 2010	MR - 2010	MR - 2010
Meldahl	MR - 2013	MR - 2010	MR - 2010	MR - 2010	MR - 2010
Montgomery	New 600' - 2010	New 600' - 2010	New 1200' - 2010	New 600' - 2010	New 600' - 2010
Newburgh	MR - 2025	MR - 2016	MR - 2016	MR - 2016	MR - 2016
Pike Island	MR - 2016	MR - 2015	MR - 2015	MR - 2016	MR - 2015
Racine	MR - 2020	MR - 2019	MR - 2020	MR - 2019	MR - 2019
RC Byrd	CR	MR - 2044	MR - 2020	MR - 2030	MR - 2033
Willow Island	MR - 2027	MR - 2027	MR - 2027	MR - 2027	MR - 2028

All lock projects at a minimum have component replacements, some have rehabs and others have new chambers added.

CR = Component Replacements
MR = Main Chamber Rehabilitation
New 600' or 1200' = New Single chamber built in place of the existing auxiliary. The old main is only used when the new chamber is down for maintenance.

1). Economic Analysis of the WPC.

Table 4 displays the incremental benefits and costs of the WPC relative to the WOPC. The ORMSS draft SIP estimates average annual incremental net benefits for meeting mainstem long term reinvestment needs range from $128 to $238 million.

Table 4.
WPC Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

	Forecast Scenario				
Ohio Mainstem System	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over WOPC	$147.8	$237.0	$259.9	$207.0	$233.3
Incremental Costs over WOPC	$19.0	$18.6	$21.5	$18.9	$18.4
Incremental Net Benefit	$128.8	$218.4	$238.4	$188.1	$214.9
Benefit / Cost Ratio	7.8	12.7	12.1	11.0	12.7
Total Costs for Optimized WPC	118.0	118.7	121.5	118.7	118.5

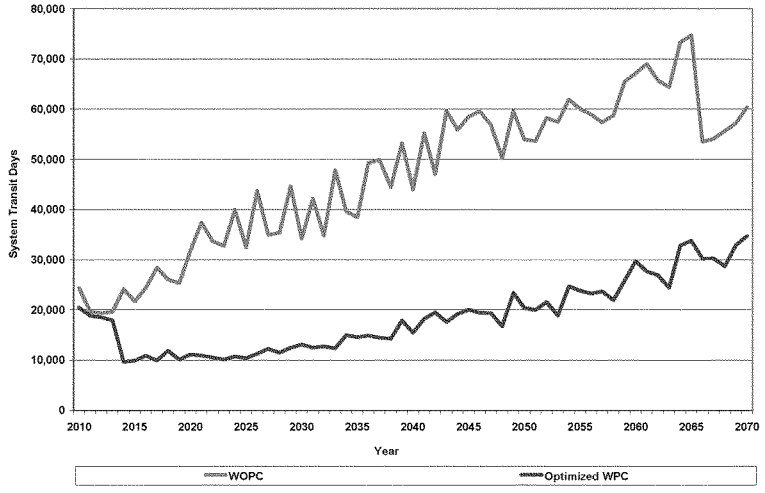
Economic analyses clearly demonstrate the value to the nation of more proactive maintenance. Relative to reactive maintenance, proactive maintenance reduces future maintenance needs and unscheduled emergency repairs, while saving hundreds of millions of dollars annually due in transportation costs. In addition, replacing the small auxiliary locks at EDM with larger locks reduces future maintenance repair costs of the 1930s vintage main chambers, avoids costly interruptions of traffic and results in transportation savings in the tens of millions annually over and above proactive maintenance alone.

The operational effect of the reactive maintenance protocol of the WOPC is illustrated (by the upper red line) in Figure 6. As the system ages, component reliability degrades and in the WOPC, components are not repaired or replaced in advance of failure. The jagged nature of the graphic reflects the interruptions due to ever increasing scheduled maintenance and the greater likelihood of unscheduled reliability lock closures. More frequent closures result in increased total transit days necessary to move projected tonnage in the ORS. In the WPC, components are repaired or replaced in advance of expected failure. The actual protocol is to estimate the expected costs of component failure through the planning period and contrast those with the expected benefits of component replacement. The decision to schedule a component replacement is based on economic efficiency, i.e., when expected benefits exceed expected costs, the component is scheduled for repair or replacement. When it is more efficient to bundle the replacement of several components, a major rehabilitation is scheduled. In every instance of proactive maintenance, expected economic benefits exceed expected economic costs. As a consequence of proactive maintenance, the number of scheduled and unscheduled closure events in the WPC is less than in the WOPC. This results in a reduced number of total transit days as illustrated (by the lower blue line) in Figure 6.

2). Environmental Sustainability in the WPC. The best WPC plan for ecosystem sustainability was the Moderate Plan, which added five specific types of measures to the WOPC; 1) increase seasonal flooding in specific habitats, 2) protect and restore habitats and diminished resources, 3) reintroduce and expand native fauna in historic ranges, 4) re-connect tributary streams and floodplains with the Mainstem Ohio River, and 5) restore wetlands in embayments. The Moderate Plan has less scientific, policy, funding, and timing uncertainties associated with it, which makes it preferable over the Maximum Plan. The added components of the Moderate Plan would require funding in addition to that provided (in the WOPC) for the Ohio River Basin Comprehensive Study and existing authorities such as Sections 206 and 1135. In those cases where new or modified authority is determined to be necessary, efforts should be directed towards obtaining such authority through the Comprehensive Ohio River Basin-wide Study. Implementation of the Moderate WPC plan would improve the long-term sustainability of freshwater mussels and riparian/floodplain resources over that of the WOPC. However, it is not expected that this plan would provide sufficient benefits to bring these resources to a state of full sustainability.

Figure 6.

Transit Days to Accommodate Equilibrium Traffic (WOPC vs. WPC)



The Lock Modernization Alternative is the best plan for long term cumulative impacts by providing a positive contribution to the environmental sustainability of water quality, fish, mussels, riparian resources, recreation, and health and safety. For example, reduction of the queuing near lock and dam projects reduces re-suspension of sediments and substrate scouring in tailwater areas which are sensitive areas for many of the remaining freshwater mussel species (some of which are federally listed) and provide important spawning habitats for several species of fish. By not diverting waterway traffic to highway and rail corridors and associated facilities, impacts of increased fuel consumption, traffic delays, air emissions, accelerated deterioration of roads, traffic-related injury, and delivery prices of diverted materials are also lessened. Implementing the projects in the Lock Modernization Alternative would result in direct and indirect impacts in the form of construction impacts and construction induced queuing. Mitigation for site-specific impacts would be incorporated into project plans developed during feasibility studies, major rehabilitation studies, or other approval processes.

It is important to note that this SIP/PEIS is a programmatic EIS under the National Environmental Policy Act (NEPA). Follow-on study reports for specific projects identified within the study planning horizon will require that site-specific impacts be evaluated during preparation of project EIS(s) or Environmental Assessment(s). Following the Council on Environmental Quality regulations, these site-specific NEPA documents will be tiered from the programmatic assessment provided through this SIP/PEIS. CEQ regulations require certain topics to be considered in any EIS. As related to ORMSS, these topics are addressed as follows:

- Adverse effects that cannot be avoided should the ORMSS recommendations be implemented in association with site-specific improvements (e.g., major rehabilitations and lock modernizations).

- Implementation of the ORMSS recommendations that would not result in irreversible or irretrievable commitment of resources without further evaluations necessary prior to approval or authorization of specific measures.

- Consideration of the relationship between short-term use of the environment and long-term productivity (or sustainability) was essential throughout the conduct of the study, with emphasis placed on both preventing degradation of and enhancing long-term sustainability. This study provides the plans for and the means to optimize returns on investments in the navigation system in combination with identification of high priority ecosystem sustainability improvements.

- All alternatives contribute to energy conservation by providing lower cost delivery of coal to utilities as compared to other delivery modes. Each successive level of navigation investment reduces tow operations fuel consumption through reduction of transit times for commodity movements.

- Coal used in power plants is a depletable natural resource and is a primary commodity transported on the Ohio River mainstem. Investment in the navigation system maintains expected levels of efficiency and service and does not alter the cost competitiveness of waterway shipment relative to other modes of delivery. For these reasons, the proposed investments are not expected to induce increased coal consumption.

- Implementation of the ORMSS recommendations would not be expected to significantly alter urban quality, historic/cultural resources, design of built environment or reuse and conservation of resources.

- No conflicts between the ORMSS recommendations and other government's land use policies, or controls were identified.

- Mitigation plans for site-specific impacts would be developed and justified during studies seeking approval or authorization for such improvements.

- Because the SIP/PEIS is a programmatic NEPA document, no additional federal permits or licenses are needed for implementation.

- Long-term sustainability of mussels and riparian/floodplain resources is an issue that remains to be resolved; however, meeting the needs of these resources will require efforts of many interests in addition to the Corps of Engineers and its cost-sharing partners under various ecosystem restoration authorities.

- Concerted efforts were made during the study process to adequately factor in uncertainties regarding reliability of lock chamber components, traffic projections under multiple scenarios, and reasonably foreseeable actions by the Corps of Engineers and others. Considering the types of concerns raised recently on other

navigation improvement studies and the publicity surrounding those studies, it is anticipated that these uncertainties could become areas of controversy for the ORMSS.

c. Future System Investment Evaluations. In 2004, total *ORS* traffic reached 270 million tons and total ORS savings exceeded $2.0 Billion. The commodity value moving on the system annually exceeds $30 Billion. The uncertainties in any system investment plan that spans sixty years coupled with the potential of under investing in the right solutions and over investing in the wrong solutions, drive the need for a program of continual reevaluation of the system investment plans. In addition, because this study focused on the mainstem locks, a follow on investment evaluation capability must be designed to encompass dams, channels and any other feature which contributes to navigation efficiency. In addition, all of the navigable tributaries should be subject to the same rigor that the current study employed. A follow on capability should be established to build on the methodologies of ORMSS and expand the evaluations to include the entire navigation infrastructure (including locks, dams and channels) on the Mainstem and the navigable tributaries. This initiative would develop and maintain the databases and models capable of providing the scientific basis for decision makers as they address the level of funding essential to provide an efficient and sustainable navigation system. The model results can be used to evaluate future investment decisions with a more holistic approach to optimize system benefits, to manage system risks, and to use performance based criteria.

6. Study Conclusions.

- The Ohio River m ainstem is an important na tural resou rce f or the nation and together with its six prim ary navigable tr ibutary rivers provides efficient water transportation for a vast portion of the Nation.

- Each of the traffic scenarios studied are reasonable assumptions of future waterway traffic demands. All of the scenarios studied show increases in navigation traffic in the study period. These scenarios present significant variations in traffic demand at specific locks, though all scenarios indicate traffic growth at a system level.

- No additional authorities are necessary at this time to address the needs related to the reliability of the locks. Follow-on studies are needed for recommended major rehabilitations and lock improvements. Further, follow-on studies are necessary to develop and refine measures to improve ecosystem sustainability.

- The need for early construction of new main lock chambers at the three upper Ohio River locks, namely Emsworth, Dashields, and Montgomery, is apparent across all traffic forecast scenarios.

- Minor repairs and small jobs associated with routine maintenance would cause only localized and limited effects on the ten VECs evaluated in the cumulative effects analysis. Routine maintenance, scheduled maintenance, and an N-Up/N-Down lockage policy would be expected to reduce tow queuing prior to passage through the locks, and to facilitate tow movement through the locks in a timelier manner and thus provide beneficial impacts (effects) on several VECs. Such beneficial effects would result from reductions in localized water turbidity levels; decreases in

habitat disturbances for fish, mussels, and riparian resources; lowered accident potentials; and improved recreation opportunities.

- High priority ecosystem sustainability measures are needed for the Ohio River, its tributaries and its associated natural resources on a large scale. These include habitat protection and restoration, control of exotic species, reintroduction of native species, improved connectivity of habitats, and reduction of sources of degradation. These measures are needed to help improve sustainability of many resources including mussels and riparian/floodplain habitats and the species they support.

- The conduct of this study was assessed in accordance with the seven Corps of Engineers Environmental Operating Principles and was found to be consistent with all of them.

- The Lock Modernization Alternative would result in reduced cumulative effects compared to the WOPC and other WPC plans. Reduction of cumulative effects would be a positive contribution to sustainability of water quality, fish, mussels, riparian resources, recreation, and health and safety.

- The Cumulative Effects Assessment indicated that future navigation investments would not adversely impact long-term resource sustainability. However, mussels and riparian/floodplain resources are not expected to become fully sustainable in the future due to continued degradation from previous actions combined with the future actions identified.

7. Study Recommendations.

ORMSS draft SIP recommendations follow. The annual costs for the SIPs over the period 2010 to 2030 are shown in Table 5.

- Increase Operation and Maintenance (O&M) investments to maximize economic efficiency. Complete all authorized navigation improvements; Olmsted, JT Myers, Greenup, Lower Monongahela, Kentucky Lock and Chickamauga.

- Provide optimal funding for the Upper Ohio River Study currently underway in order for this project to be included in a WRDA in the FY 2010 time frame.

- Initiate main chamber rehabilitation studies for Meldahl, Hannibal, and Myers and complete by 2009. Initiation of design of these efforts should begin in 2010.

- Initiate main chamber rehabilitation study for Pike Island to complete in 2014.

- Pursue planning and implementation of measures to improve environmental sustainability in collaboration with other interests.

- Incorporate all Reasonable and Prudent Measures into the Operation and Maintenance of the river.

- Complete work on the Markland gates as soon as possible. Funds provided in FY 2006 will initiate design and continued funding in FY 2007 and beyond will be used to construct the gates and place them in service.

- All detailed evaluation of site-specific impacts for follow on studies and other actions would be tiered from the SIP/PEIS.

- Initiate the Ohio River Basin Comprehensive Study in order to assess water resource opportunities throughout the basin in collaboration with other interests. Planning efforts should include identification and evaluation of opportunities to improve environmental sustainability throughout the basin including the tributaries.

- Establish a stand alone program (Ohio River Navigation System Investment Program) to update the data and models used in preparing the System Investment Plan. Expand the program capability to include the Ohio River dams and include tributary (Allegheny, Monongahela, Kanawha, Green, Tennessee and Cumberland Rivers) locks and dam structures to support navigation investment decisions and manage future system risk. Use these tools in annual budget formulation.

- Use the Ohio River Navigation System Investment Program to reexamine the medium and long term needs identified in the SIP to optimize investments on these projects.

- All detailed evaluation of site-specific impacts for follow on studies and other actions would be tiered from the SIP/PEIS.

- The Federal budget was not considered as a constraint in the development of the System Investment Plan. Follow on actions need to be conducted to analyze investment strategies with a constrained federal budget and expanded to include all navigation locks, dams and channels on the Ohio River and its navigable tributaries.

Table 5
Annual Costs of Optimal SIP Actions,
By Scenario Over Time Period 2010 to 2030
($ Millions)

Year	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
2010	237.87	237.67	238.25	237.45	237.43
2011	124.76	134.59	135.39	127.90	134.41
2012	107.97	111.76	112.67	108.67	111.78
2013	92.95	95.83	95.75	100.90	95.94
2014	231.80	280.39	216.65	285.21	281.20
2015	292.74	295.82	320.75	289.95	294.27
2016	292.61	295.95	323.06	295.10	299.68
2017	152.21	100.12	205.62	101.66	95.86
2018	91.01	101.02	96.56	106.10	91.00
2019	72.95	84.09	73.13	85.60	78.40
2020	72.27	79.11	74.84	80.00	76.83
2021	78.02	73.38	79.94	73.32	73.40
2022	73.59	64.86	69.22	64.80	67.12
2023	67.55	66.20	66.85	66.13	68.46
2024	56.24	55.09	55.35	55.01	56.73
2025	69.22	66.38	62.18	64.39	62.23
2026	69.70	57.68	59.92	57.59	57.69
2027	78.33	68.10	68.76	68.26	61.86
2028	63.57	64.78	63.70	62.40	71.40
2029	71.51	66.54	64.39	66.27	79.29
2030	74.44	66.18	73.36	71.70	74.93

SECTION 1
STUDY AUTHORITY

1. The basic authority for the Ohio River Mainstem Study (ORMSS), is contained in the resolution adopted by the Committee on Public Works of the United States Senate dated 16 May 1955:

> Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Ha rbors created under Section 3 of t he River and Harbor Act, approved June 13, 1902, be, and is hereby req uested to rev iew the reports on th e Ohio River published in H ouse Document No. 306, Sevent y-fourth Congress, First Session, House Co mmittee on Flood Control Docu ment No. 1, Seventy-fifth Congress, First Session, and rela ted reports, with a view to determining whether any modifications in the present comprehensive plan for flood contr ol and other purposes in the Ohio River basin is advisable at this time.

2. Further authority was provided through a resolution adopted by the U.S. House of Representatives Committee on Public W orks and Transportation adopted 11 March 1982. This resolution reads as follows:

> Resolved by the Committee on Public Works and Transportation of the House of Represent atives, Unite d States, that th e Board of Engineers for Rivers and Harbors established by the Section 3 of the River and Harbor Act approved Ju ne 13, 1902, is hereb y requested to review th e reports on the Ohio River published as House Document No. 492, 60th Congress, First Se ssion, and H ouse Docume nt No. 306, Seventy-fourth Congress, First S ession, and other pertinent reports with a view to determ ine whether an y m odification in the au thorized plan for modern barg e navigation and other purposes on the Ohio River is advisable at this tim e with particular emphasis on need for im provement or replacement of Em sworth Locks and Dam, Oh io River Mile 6.1; Dashield s Locks and Dam , Ohio River Mile 13.3; Montgomery Island Locks and Dam , Ohio Ri ver Mile 31.7; and other loc ations where obsolete or inadequate facilities impede the orderly flow of commerce.

SECTION 2
PURPOSE AND SCOPE

1. This section provides the purpose and scope for the primary output of this study; a System Investment Plan (SIP) that identifies potential navigation improvement projects on the Ohio River and fully considers the environmental sustainability needs for the Ohio River and associated floodplains. Purpose and scope discussions are extended for two related environmental documents. The direct, indirect, and cumulative effects of the plan itself are described in a Programmatic Environmental Impact Statement (PEIS). The Cumulative Effects Assessment (CEA) addresses the accumulation of meaningful impacts to the Ohio River study area due to all past, present, and reasonably foreseeable future actions both by the Corps of Engineers and others. Section 2.1 describes the purposes for each of these products and the need for their development at this point in time. The scope of studies to develop each product is contained in Section 2.2. Section 2.3 contains the overall report organization. The plan formulation process is described in Section 2.4, and study participants and roles are listed in Section 2.5.

2. A large-scale, long-term study such as ORMSS inevitably evolves from its inception to its completion because additional knowledge and insights are gained and institutional approaches change. Three important project components evolved during ORMSS and form the cornerstones of the study framework:

- The **Federal decision-making process** for ORMSS developed in a distinctive way that generated many possible study outcomes and recommendations related to navigation investment options. More typical feasibility studies tend to identify a narrower set of alternatives.

- The Corps' **Environmental Operating Principles**, introduced and formalized during this study, have outlined important environmental imperatives for the Corps' operations in the 21st century. These principles incorporate synergy, sustainability, interdependence, and collaboration along with other concepts exemplified by ORMSS.

- **Innovation in project design and development** form the third important cornerstone, resulting in an integrated study characterized by its cutting-edge approach and comprehensiveness.

These three components permeate the ORMSS study and will be discussed in greater detail in other sections of this PEIS and accompanying documents.

2.1 STUDY PURPOSE & NEED FOR ACTION

1. The goal of the Ohio River Mainstem Systems Study (ORMSS) is to identify the best long-term comprehensive program for maintaining a viable navigation system on the main stem of the Ohio River while striving to achieve environmental sustainability[1]. The primary purpose of the Ohio River Mainstem Systems Study (ORMSS) is to develop the best System Investment Plan (SIP) for maintaining safe, environmentally sustainable, and reliable navigation on the Ohio River over a 60-year period from 2010 to 2070. Specifically, the study evaluates the need for maintenance of major lock components, including replacement and major rehabilitation, opportunities for operational efficiency and low cost structural measures, and new lock construction needs and for all 19 navigation lock and dam sites on the Ohio River Mainstem from 2010 – 2070 with an aim to identify the optimum plan for meeting these needs during that time period[2]. The study also identifies high priority needs for improving sustainability of aquatic and riparian/floodplain resources. The current system is shown in **Figure 2-1** and each lock and dam is described in **Table 2-1** (which does not include Locks and Dams 52 and 53 as they will shortly be replaced with the new Olmsted project). These lock and dam structures are crucial to the efficient passage of commodities throughout the Ohio River Basin. Typical Ohio River tows must lock through several of these facilities during their trips. Any lockage delays translate to increased transportation costs and additional costs to consumers.

2. As traffic grows within the Ohio River Valley and the current infrastructure becomes less reliable, commercial traffic will experience greater delays in locking through these facilities for two main reasons. Increased traffic will result in greater number of tows desiring to lock through many projects and result in greater amounts of time that tows must spend waiting in line to lock through even when the locks are operating efficiently. Less reliable locks will translate into greater down times to repair failed components and will be particularly onerous during closures of the larger (or main) chambers. During these times, traffic will be forced through smaller lock chambers at many projects. As documented later in this report (Section 6), closures of the main chambers along the Ohio River result in extremely large delays to barge traffic (and high additional costs passed on to consumers). Therefore a large focus of this study is reducing or eliminating these particularly onerous closures in an economically efficient manner.

3. In the course of the study, the Corps will also assess current management practices, infrastructure and operations/maintenance practices to seek ways to balance the needs of both navigation and natural systems.

4. In response to stakeholder input, the study was modified to include identification of measures to improve ecological sustainability to provide a balance between economic and environmental improvements.

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[1] Environmental sustainability is defined in Corps Engineer Circular 1105-2-404 (PLANNING CIVIL WORK PROJECTS UNDER THE ENVIRONMENTAL OPERATING PRINCIPLES, 1 May 2003) as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations."

[2] Currently, there are 20 lock and dam sites on the Ohio River, but after completion of Olmsted L&D, tentatively scheduled for 2009, L/Ds 52 and 53 will be subsequently decommissioned and removed.

5. The purpose of the System Investm ent Plan, Programmatic Environm ental Impact Statement, and Cumulative Effects Assessment, is briefly discussed in Section 2.2.

2.1.1 System Investment Plan

1. The primary purpose of the Ohio River Mainstem Systems Study (ORMSS) is to develop the best System Investment Plan (SIP) for maintaining safe, environmentally sustainable, and reliable navigation on the Ohio River over a 60-year period from 2010 to 2070. Another purpose is to identify high priority needs to improve ecosystem sustainability for the Ohio River. To do this, the SIP will identify where, and approximately when, various investments should be made along the Ohio River during the time period 2010-2070. **The SIP does not recommend any specific projects for Congressional authorization**; such authorizations would result from future Feasibility studies that focus on site-specific improvements. From information developed in the SIP, the schedule of these future feasibility studies will be developed. Development of this schedule and budget for future studies will help ensure the completion of these efforts such that improvements are in place when needed.

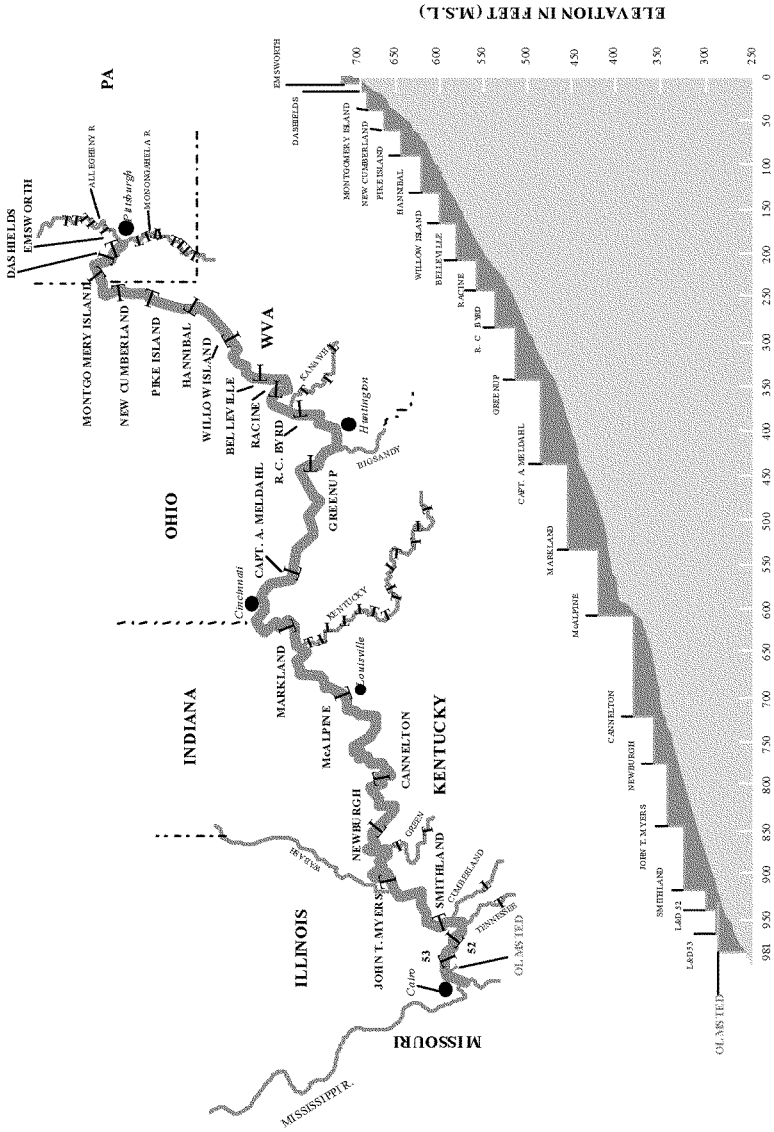
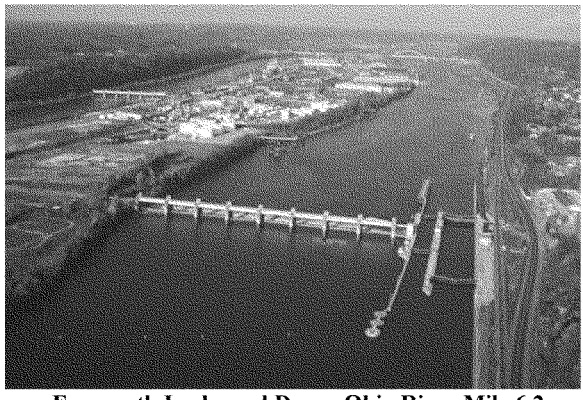


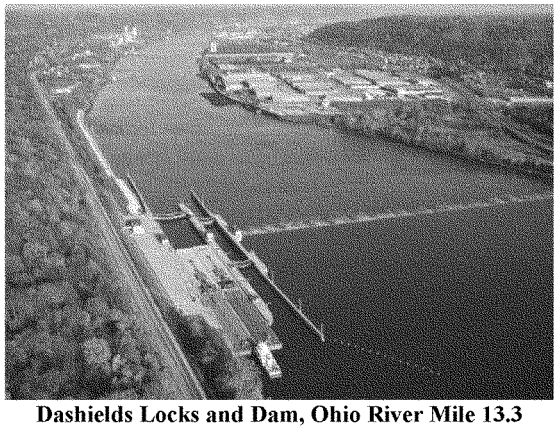
Figure 2-1. Plan and Profile of the Ohio River Lock and Dam System

TABLE 2-1
Description of Ohio River Locks and Dams



Emsworth Locks and Dams, Ohio River Mile 6.2

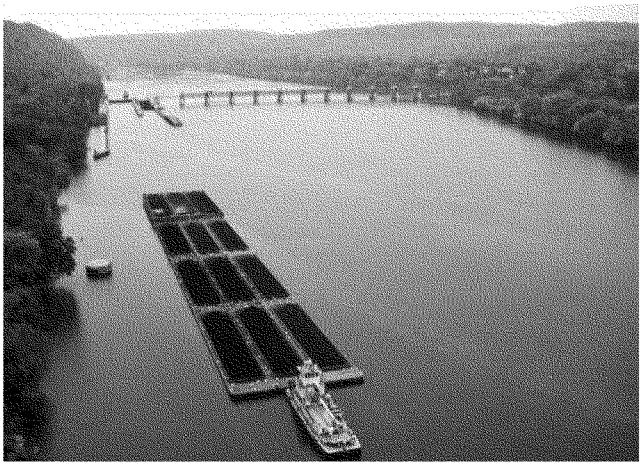
LOCKS: Two parallel locks, main lock 110' by 600', auxiliary lock 56' by 360'.
DAMS: Non-navigable, gated dams on main + back channels. Main Channel comprised of 8 vertical-lift gates, each 100' in length, with one fixed weir with 34' open crest. Top length of dam is 967'. Back Channel composed of 6 vertical-lift gates, each 100' in length. Top length of dam is 750'. Lift is 18.0'. Operation Commenced: 1921. # Vessel Lockage Cycles[3] in 2003: Main-6569; Auxiliary-4368. Federal Energy Regulatory Commission (FERC) hydropower preliminary permits are active (i.e. a non-Federal entity is studying the feasibility of constructing a hydroelectric plant) at the both dams.



Dashields Locks and Dam, Ohio River Mile 13.3

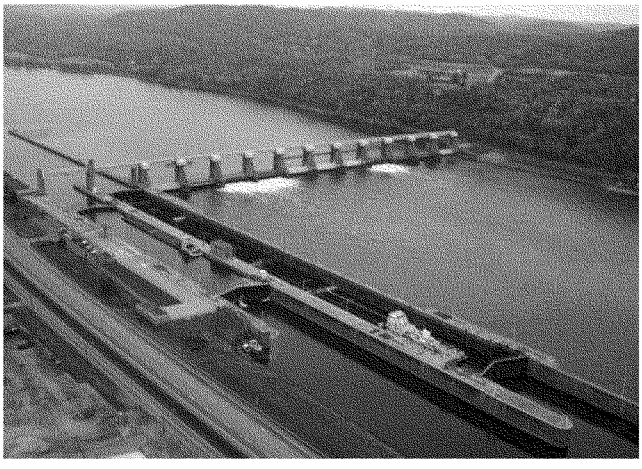
LOCKS: Two parallel locks, main lock 110' by 600' (actual length is 599.25', the 600' length will be used in this report for ease and convenience.), auxiliary lock 56' by 360'. DAM: Fixed Crest Weir, top length of dam 585'. Lift is 10.0'. Operation Commenced: 1929. # Vessel Lockage Cycles in 2003: Main 6612; Auxiliary-3550. FERC Preliminary Permit is active.

[3] A vessel lockage cycle is required for both the emptying or filling of the lock required by a vessel lockage and a "turnback" which occurs when the lock is turned back empty in order to service a vessel going in the same direction as the previous vessel.



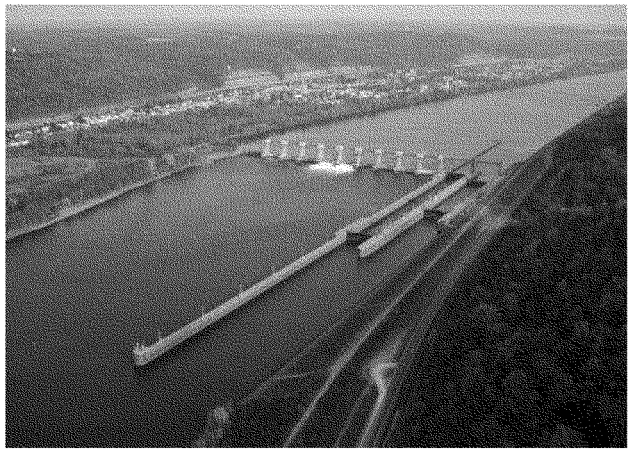
Montgomery Locks and Dam, Ohio River Mile 31.7

LOCKS: Two parallel locks, main lock 110' by 600' (actual length is 597.0', the 600' length will be used in this report for ease and convenience), auxiliary lock 56' by 360'. DAM: Non-navigable dam comprised of 10 vertical-lift gates, each 100' in length, with two fixed weirs, each with a 101.5' open crest length. Top length of dam is 1,379'. Lift is 17.5'. Operation Commenced: 1936 # Vessel Lockage Cycles in 2003: Main-6772; Auxiliary-3164. FERC Preliminary Permit is active.



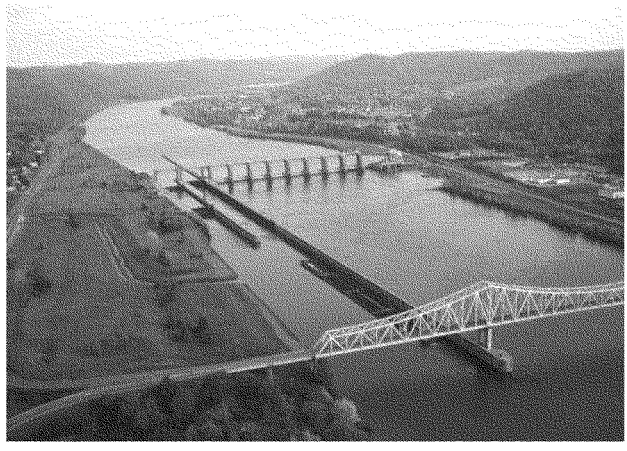
New Cumberland Locks and Dam, Ohio River Mile 54.4

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 11 tainter gates, each 110' in length. Top length of dam is 1,315'. Lift is 20.5'. Operation Commenced: 1956 # Vessel Lockage Cycles in 2003: Main-5012; Auxiliary-2766. Surrender of hydropower license was accepted by FERC in October 2009.



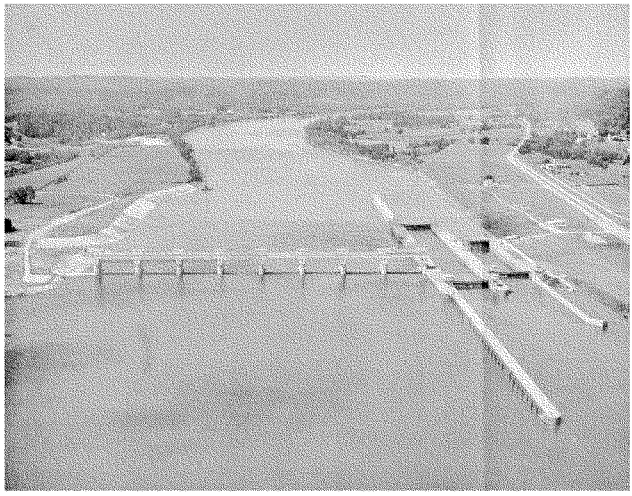
Pike Island Locks and Dam, Ohio River Mile 84.2

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 9 tainter gates, each 110' in length, and one 196' fixed weir section. Top length of dam is 1,306'. Lift is 21.0'. Operation Commenced: 1963
Vessel Lockage Cycles in 2003: Main-5875; Auxiliary-2499. FERC hydropower license (i.e. authorization from FERC to construct plant) is active.



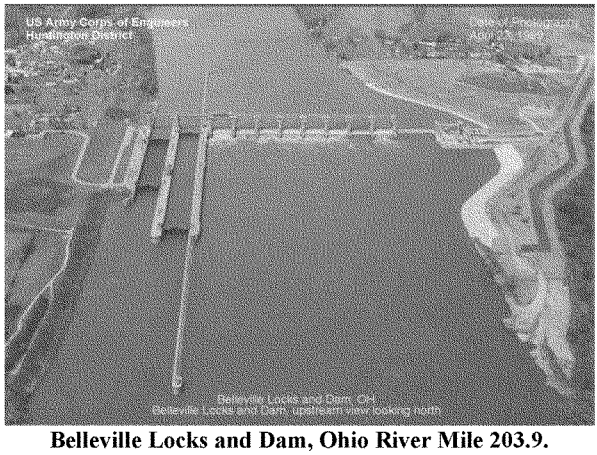
Hannibal Locks and Dam, Ohio River Mile 126.4.

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 8 tainter gates, each 110' in length, and one 79' fixed weir section. Top length of dam is 1,306'. Lift is 21.0'. Operation Commenced: 1972 # Vessel Lockage Cycles in 2003: Main-5933; Auxiliary-1308. Non-Federal hydroelectric plant is located on abutment side.



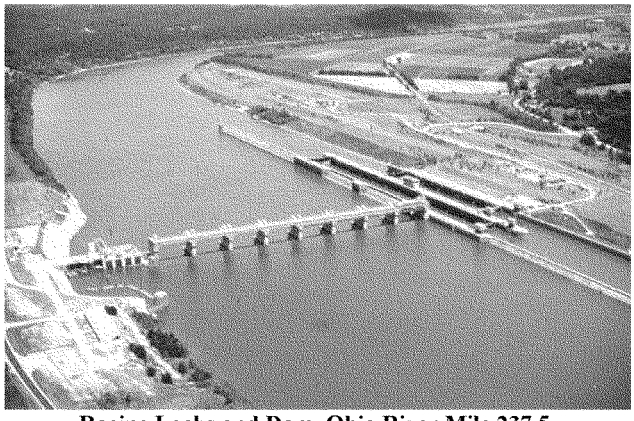
Willow Island Locks and Dam, Ohio River Mile 162.4.

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 8 tainter gates, each 110' in length, and one 84' fixed weir section. Top length of dam is 1,128'. Lift is 20.0'. Operation Commenced: 1972
Vessel Lockage Cycles in 2003: Main-5459; Auxiliary-1777. FERC hydropower license is active.



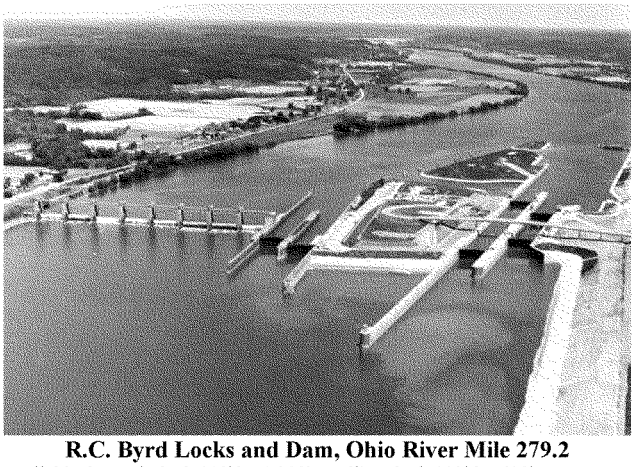
Belleville Locks and Dam, Ohio River Mile 203.9.

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 8 tainter gates, each 110' in length, and one fixed weir section with 130' open crest. Top length of dam is 1,206'. Lift is 20.0'. Operation Commenced: 1968.
Vessel Lockage Cycles in 2003: Main-5789; Auxiliary-1084. Non-Federal hydroelectric plant is located on abutment side.



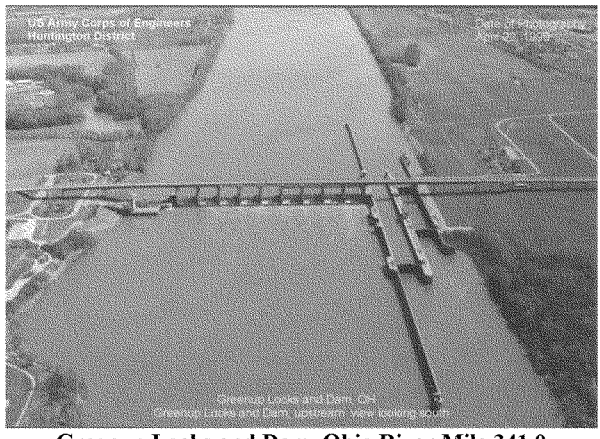
Racine Locks and Dam, Ohio River Mile 237.5.

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 8 tainter gates, each 110' in length, and one fixed weir section with 130' open crest. Top length of dam is 1,160'. Lift is 22.0'. Operation Commenced: 1967.
Vessel Lockage Cycles in 2003: Main-5996; Auxiliary-1160. Non-Federal hydroelectric plant is located on abutment side.



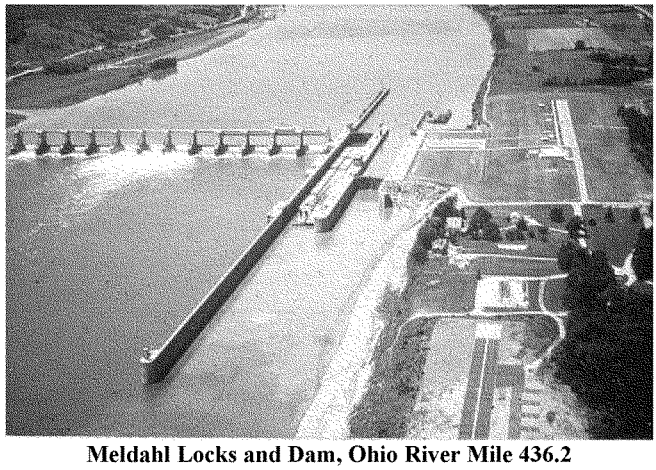
R.C. Byrd Locks and Dam, Ohio River Mile 279.2

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'
DAM: Non-navigable dam composed of 8 roller gates, each 125.5' in length. Top length of dam is 1,206'. Lift is 23.0'. Note: The operating locks are the rightmost (landward) pair, each with two sets of lock gates visible. Operation Commenced: 1993. # Vessel Lockage Cycles in 2003: Main-6320; Auxiliary-1494. FERC hydropower license is active.



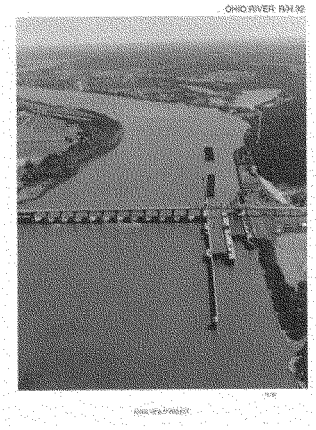
Greenup Locks and Dam, Ohio River Mile 341.0

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 9 tainter gates, each with 100' clear span, and one fixed weir section with 223' open crest. Top length of dam is 1,206'. Lift is 30.0'. Operation Commenced: 1959. # Vessel Lockage Cycles in 2003: Main-7292; Auxiliary-3379. Non-Federal hydroelectric plant located on abutment side.



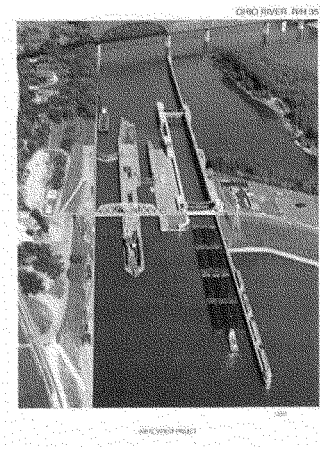
Meldahl Locks and Dam, Ohio River Mile 436.2

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 12 tainter gates, each with 100' clear span, and one fixed weir section with 310' open crest. Top length of dam is 1,756'. Lift is 30.0'. Operation Commenced: 1962. *# Vessel Lockage Cycles in 2003: Main-7028; Auxiliary-1843. FERC hydropower license is active.



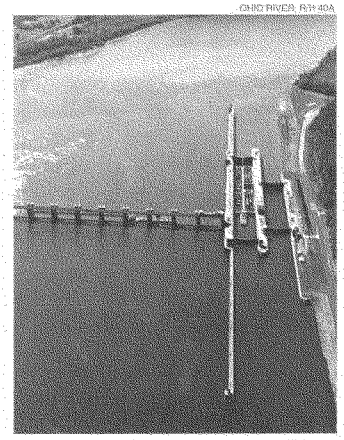
Markland Locks and Dam, Ohio River Mile 531.5

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 12 tainter gates, each with 100' clear span. Top length of dam is 1,395'. Lift is 35.0'. Operation Commenced: 1959. # Vessel Lockage Cycles in 2003: Main-5983; Auxiliary-2012. Non-Federal hydroelectric plant located on abutment side.



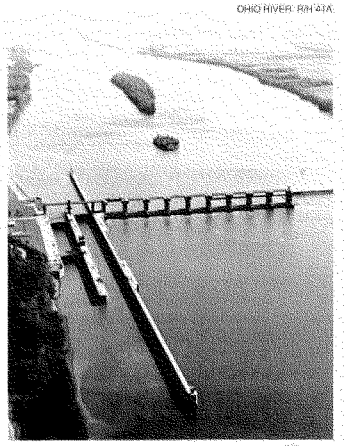
McAlpine Locks and Dam, Ohio River Mile 606.8

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 1200'. Second 110' by 1200' lock opened in 2009.
DAM: Consists of fixed weir and tainter gate sections. . Lift is 37.0'. Operation Commenced: 1961. # Vessel Lockage Cycles in 2003: Main-8073; Auxiliary-0 (Being Reconstructed). Non-Federal hydroelectric plant located on abutment side.



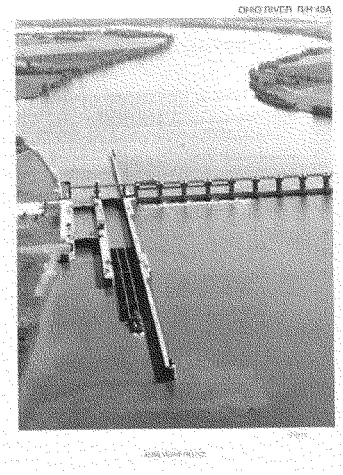
Cannelton Locks and Dam, Ohio River Mile 720.7

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 12 tainter gates, each with 100' clear span, and one fixed weir section with 195' crest. Top length of dam is 1,395'. Lift is 25.0'. Operation Commenced: 1971.
Vessel Lockage Cycles in 2003: Main-6935; Auxiliary-1319. FERC hydropower license is active.



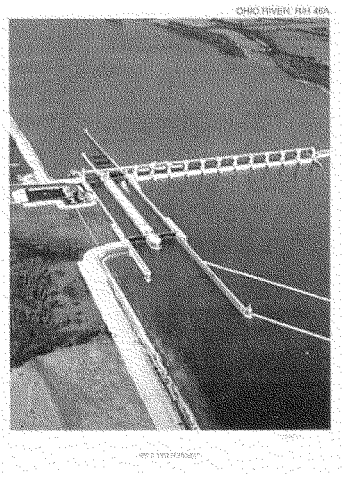
Newburgh Locks and Dam, Ohio River Mile 776.1

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 9 tainter gates, each with 110' clear span, and one fixed weir section 1300' long. Top length of gated dam is 1,140'. Lift is 25.0'. Operation Commenced: 1975.
Vessel Lockage Cycles in 2003: Main-8354; Auxiliary-1454. FERC hydropower preliminary permit is active.



J.T. Myers Locks and Dam, Ohio River Mile 846.0

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 600'.
DAM: Non-navigable dam composed of 10 tainter gates, each with 110' clear span, and one fixed weir section 2,239' long. Top length of gated dam is 1,265'. Lift is 22.0'. Operation Commenced: 1975.
Vessel Lockage Cycles in 2003: Main-7929; Auxiliary-2626. FERC hydropower preliminary permit is active



Smithland Locks and Dam, Ohio River Mile 918.5

LOCKS: Two parallel locks, main lock 110' by 1,200', auxiliary lock 110' by 1,200'.
DAM: Non-navigable dam composed of 11 tainter gates, each with 110' clear span, and one fixed weir section 1,572' long. Top length of gated dam is 1,390'. Lift is 22.0'. Operation Commenced: 1979.
Vessel Lockage Cycles in 2003: Main-6503; Auxiliary-6963. FERC hydropower license is active.

2.1.2 Programmatic Environmental Impact Statement

1. The purpose of the Programmatic Environmental Impact Statement (PEIS) under the National Environmental Policy Act (NEPA) is to document consideration of various alternative Federal actions formulated to meet overall program goals and disclose environmental impacts associated with those alternatives prior to making any decisions. For this study, the No-Action alternative (also called the Without-Project Condition) is assessed as required by NEPA. The focus of this PEIS differs from EIS's developed in the past for impacts of specific project(s). This PEIS presents sufficient economic, engineering, and environmental information to evaluate broad system investment alternatives. The PEIS also provides information regarding overall impacts of the program, including system-wide cumulative effects, so that the decision-makers can make a reasoned judgment of the merits of the actions at the present stage of planning or development through consideration of effects of navigation improvements on environmental sustainability. This SIP/PEIS also provides information on sustainability needs for ecological resources throughout the study area.

2. According to regulations of the Council on Environmental Quality for implementing NEPA, the PEIS is required to contain specific subject material. Since the format of this report differs significantly from a standard PEIS, **Table 2-2** is provided to assist the reader in locating the required sections.

Table 2-2
Location of Subject Material Required by the National Environmental Policy Act of 1969

SUBJECT	LOCATION
Cover Sheet	Cover Sheet
Summary Executive	Summary
Table of Contents	Table of Contents
List of Preparers	Section 13
List of Agencies, Organizations and persons to whom copies of the statement are sent	Section 11
Index	Table 2-3 and Index
Purpose of and need for action	Section 2.1
Alternatives	Section 8, 9
Affected Environment	Section 5
Environmental Consequences	Sections 8, 9, 10
Appendices	

3. The PEIS index should have a level of detail sufficient to focus on areas of the PEIS of reasonable interest to any reader. Sections within this report that deal with environmental issues are shown in **Table 2-3**. This table provides the reader interested in tracking the environmental discussion with the pertinent topics to review.

TABLE 2-3
Environmental Content in System Investment Plan
For Ohio River Mainstem Study

2. PURPOSE AND SCOPE Introduction 2.1 STUDY PURPOSE & NEED FOR ACTION 2.1.2 Programmatic Environmental Impact Statement 2.1.3 Cumulative Effects Assessment 2.2 SCOPE OF STUDIES 2.2.1 System Investment Plan 2.2.2 Programmatic Environmental Impact Statement 2.2.3 Cumulative Effects Assessment 2.4 STUDY PLAN FORMULATION PROCESS
SECTION 5 – AFFECTED ENVIRONMENT Complete section
6. OHIO RIVER PROBLEMS, NEEDS AND OPPORTUNITIES 6.1 BACKGROUND - ECOSYSTEM BENEFITS 6.1.4 Ecosystem Considerations – Environmental Operating Principles 6.2 Planning Objectives - Enhancing Environmental Sustainability 6.4 PROBLEMS AND OPPORTUNITIES RELATED TO ENVIRONMENTAL SUSTAINABILITY 6.4.1 Identification of Environmental Sustainability Concerns and Opportunities 6.4.1.1 Environmental Sustainability of Priority Valued Environmental Components (VECs) 6.4.1.1.1 Water and Sediment Quality VEC 6.4.1.1.2 Fish VEC

TABLE 2-3
Environmental Content in System Investment Plan
For Ohio River Mainstem Study

6.4.1.1.3 Mussels 6.4.1.1.4 Riparian/Floodplain Resources 6.4.1.1.5 Health and Safety 6.4.1.1.6 Recreation 6.4.1.2 VEC Interdependencies 6.4.2 Environmental Sustainability Concerns and Opportunities For Ohio River Aquatic and Riparian Resources 6.5.1 Navigation Stewardship Program 6.5.5 Additional Environmental Sustainability Improvement Options
8. OHIO RIVER MAINSTEM WoPC FORMULATION AND ASSESSMENT 8.5 ECOSYSTEM MEASURES - EXISTING ECOSYSTEM AUTHORITIES 8.5.1 Existing Corps Authorities and Regulatory Responsibilities 8.5.2 Sustainability Focus for Mitigation and Design 8.5.3 Other Agencies' Authorities and Regulatory Responsibilities 8.7 EVALUATION OF THE REACTIVE MAINTENANCE ALTERNATIVE (WITHOUT PROJECT CONDITION) 8.7.2 Impacts to Valuable Environmental Components 8.7.3 Cumulative Effects 8.8 EVALUATION OF ECOSYSTEM SUSTAINABILITY MEASURES 8.8.1 Methodology 8.8.2 Sustainability in the Without-Project Condition 8.9 REMAINING PROBLEMS AND OPPORTUNITIES 8.9.3 Environmental Considerations
9. FORMULATION OF ALTERNATIVE SYSTEM INVESTMENT PLANS 9.3.8 Refinements To Accommodate Environmental Concerns 9.4 SUSTAINABILITY MEASURES (NOT RELATED TO LOCK CONSTRUCTION) CONSIDERED 9.4.1 Existing Authorities 9.4.2 Seeking Additional Authorities 9.7 FORMULATION OF ECOSYSTEM RESTORATION WITH-PROJECT ALTERNATIVE 9.7.1 Impacts to Valuable Environmental Components 9.7.2 Cumulative Effects 9.8 EVALUATION OF ECOSYSTEM SUSTAINABILITY MEASURES 9.8.1 Methodology 9.8.2 Sustainability in the With Project Condition 9.9 REMAINING PROBLEMS AND OPPORTUNITIES
10 EVALUATION OF ALTERNATIVE SYSTEM INVESTMENT PLANS 10.2 ENVIRONMENTAL CONSEQUENCES OF NAVIGATION MEASURES 10.2.1 Impacts of WOPC and WPC Alternatives on Major VECS 10.2.2 Cumulative Effects 10.2.2.1 Approach To Analyzing Cumulative Effects 10.2.2.2 Environmental Sustainability Conclusions By Valued Environmental Component 10.2.2.3. Interactions With Other Valued Environmental Components 10.2.2.4. ES Overview Of All VECs 10.2.3 DISCUSSION OF DIRECT AND SECONDARY INFLUENCES 10.2.3.1 Eroded Savings 10.2.3.2 Transit Time 10.2.4.3 Diverted Traffic 10.2.4.4 Construction Impacts of WPC Alternatives 10.2.4.5 Expansion of Terminals and Fleeting Areas

TABLE 2-3
Environmental Content in System Investment Plan
For Ohio River Mainstem Study

10.2.4.5.1 Impacts of Intermodal Facilities
10.2.4.5.2 Fleeting Areas on the Ohio River
10.2.4.6 SUMMARY OF NAVIGATION PREDICTIVE ANALYSIS TECHNIQUE (NAVPAT)
10.2.3.6.1 Input Considerations
10.2.3.6.2 Output Features
10.2.3.6.3 Discussion of Results
10.2.3.6.4 Anticipated Improvements to the NAVPAT Model
10.3 COMPARISON OF ALTERNATIVE SYSTEM INVESTMENT PLANS (SIPS)
10.3.1 Requirements from the Corps' Planning Process
10.3.2 Requirements from the NEPA Process
10.3.3 Screening Process for Navigation-Related Plans
10.3.4 Description of Components within the Navigation-Related Alternative Plans
10.3.5 Prioritization Process for Environmental Sustainability-Related Plans
10.3.6 Overall Comparisons of the Alternative Plans
10.3.7 Detailed Comparison of the Alternative Plans
10.3.8 The Combined NED/NES Plan

2.1.3 Cumulative Effects Assessment

1. Consideration of cumulative effects is a requirement of the National Environmental Policy Act as described in regulations issued by the President's Council on Environmental Quality (CEQ) and in the guidance document "Considering Cumulative Effects Under the National Environmental Policy Act," 1997, Executive Office of the President, Washington, D.C. As such, a cumulative effects assessment is a central focus in Programmatic Environmental Impact Statements. In a system-wide study such as the ORMSS, it is important to consider the cumulative effects of possible actions within the context of the CEQ definition. CEQ defines cumulative effects as follows (40 CFR 1508.7 and 1508.8):

> "Cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

2. Consideration of cumulative effects requires a broader perspective than examining just the direct and indirect effects of a proposed action. It requires that future impacts be assessed in the context of past and present effects to each important resource. Often it requires consideration of a larger geographic area than just the immediate "project" area. One of the most important aspects of cumulative effects assessment is that it requires consideration of how actions by others (including those actions completely unrelated to the proposed action) have and will affect the same resources. In assessing cumulative effects, the key determinant of importance or significance is whether the incremental effect of the proposed action will alter the sustainability of the resource in light

of other effects that resource has experienced up until the present and/or will experience in the future.

3. The Cumulative Effects Assessment (CEA) for the ORMSS analyzes the impacts on the environment that result from implementation of the Ohio River mainstem navigation system modernization features and ecosystem sustainability measures of the SIP when added to other past, present and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Guidance provided by CEQ in 1997 was followed in conducting the CEA for the ORMSS. CEQ's guidance document describes an 11-step process, with the steps grouped into three larger assessment phases (scoping, describing the affected environment, and determining the environmental consequences). The process of analyzing cumulative effects enhances traditional approaches used in environmental impact assessment in that it focuses the analysis on the resources potentially affected rather than just on the action being proposed.

4. The CEA report is in the Environmental Appendix to this SIP/PEIS. The CEA was prepared considering a reasonable upper limit of possible navigation improvement needs identified through the ORMSS in order to examine the total effects to each resource. For this reason comparisons among alternatives are made in the SIP/PEIS rather than in the CEA report.

2.2 SCOPE OF STUDIES

2.2.1 System Investment Plan

1. This System Investment Plan (SIP) considers economic, social, and environmental aspects of lock modernization as well as maintenance and operational efficiency and low-cost structural measures at all 19 Ohio River navigation facilities as well as measures undertaken to improve ecosystem sustainability. The planning horizon for all economic, engineering and environmental analyses addressed by this report is 2010-2070.

2. Maintenance activities include routine or day-to-day maintenance, cyclical maintenance, replacement or repair of major lock components, and major rehabilitation of those components. The focus of major rehabilitation is to restore the functioning of existing locks, not on construction of larger locks.

3. Operational efficiency and low-cost structural improvements include measures where the Corps has authority to construct and generally costing less than $10 million in capital costs. Measures to improve operational efficiency are also considered. Examples of small-scale improvements include:

- Installation of per manent m ooring buoys or cells near lock approach points (which could enhance tow m ooring in queuing situations and possibly speed up double-cut processing);
- Extension of guide or guard walls to improve lock approach times;,

- Implementation of traffic m anagement policies whereby the Corps would schedule arrivals of comm ercial tows at some or all Ohio River locks in an attempt to reduce delays during main chamber closures.

4. Full consideration of maintenance and operational efficiency and low-cost structural measures is made both without and with large-scale lock modernization improvements in an attempt to maximize project performance prior to recommending any large-scale investments.

5. Examples of lock modernization improvements include:

- the lengthening of existing 600' x110' auxiliary cham bers at projects with an existing 1200'x110' main chamber,
- provision of replacement locks at the three oldest facilities on the Ohio River, namely Emsworth, Dashields, and Montgomery Locks & Dams.

6. The study also takes into consideration the environmental costs and benefits in its recommendations. Environmental inputs into the planning process are not quantified in economic terms. Therefore, when possible, these inputs address habitat impacts or effects on the ability of the environment to sustain a given resource.

7. Currently, improvements are already underway (or authorized) at the following sites on the Ohio River:

- Olmsted Locks and Dam – now under construction near Olmsted, Illinois – replaces two v ery old structures, L&D 52 and L&D 53. This work is assumed to be operational before 2010.
- McAlpine L ocks and Dam – construction to replace one of the oldest components of the system -- the existing 70-year old landside 600-foot chamber -- with a new 1200-foot lock chamber has been com pleted. This new lock became operational in 2009.
- Greenup and Myers Locks and Dams – preliminary engineering and design has begun to extend the existing 110'x600' auxiliary chamber at each site to 1200' through construction of approach walls, an intake structure, culverts and valves. These improvements were recommended in the Greenup/Myers Feasibility Study, an interim feasibility study conducted as part of ORMSS (see Section 3.1). Also at each site, the main chamber lock gates will be modified to accommodate a Miter Gate Quick Changeout System. The new Greenup lock extension is assum ed to be operational before 2010, the lock extension at Myers is assumed to become operational by 2012. Since the authorization for these tw o structures was achieved under the ORMSS program, the Corps has agreed to include these two projects in the CEA as part of total navigation improvements resulting from the ORMSS.
- The Ohio River Ecosystem Restoration Program was authorized in WRDA 2000. However, the Ohio River Ecosystem Restoration Program has yet to receive Congressional appropriations for

implementation. As such, the program is now on the candidate list for de-authorization. Therefore, it is still mentioned in the final SIP/PEIS, although it is not includ ed as a reasonably foreseeable future action in either the Without or With Project Conditions.

In accordance with Corps guidance, the improvements listed above will be considered complete in all system-wide alternatives considered in this report.

8. To address concerns about uncertain traffic demands on the Ohio River, alternative traffic demand scenarios have been developed. There is actually a series of System Investment Plans developed to correspond to each traffic scenario (See Section 2.4).

2.2.2 Programmatic Environmental Impact Statement

1. The Programmatic Environmental Impact Statement (PEIS) documents the consideration of impacts resulting from implementation of all actions determined to be appropriate through the planning horizon (2010-2070), including maintenance, operational efficiency and low cost structural measures, and high-cost lock modernization activities. The PEIS also assesses the effects of environmental sustainability alternatives developed as part of the ORMSS. Drawing from information in the Environmental Appendix, the PEIS includes comparisons among alternatives being considered. In order to fulfill commitments made during the Greenup and Myers Interim Feasibility study, the PEIS examines the incremental impacts of including those two projects only in future WPC system investment plans.

2. The final report should not be viewed as a one-time plan for the next 60 years. Once the final report is completed, an on-going Monitoring and Adaptive Management phase may be recommended to assess changes in needs and to respond by adjusting the plan accordingly to reflect the most up to date set of conditions and forecasts. The tools being developed through the current study will provide the means to monitor and adapt at a reasonable cost such that the plan continues to optimize the Federal investment.

3. Tiering is a process in NEPA that encourages examination of b Revised May 09 concerns at a programmatic level, followed by examination of narrower, site-specific issues at an individual action or project level. This is the process that has been pursued for the ORMSS. The current SIP/PEIS is a system-wide study wherein relatively larger scale matters (e.g., system-wide effects, cumulative effects, etc.) are assessed. Following development of the SIP/PEIS, site-specific studies and proposals would be prepared. Effects of each of these actions would be assessed in subsequent tiers of NEPA documents (Site-specific Environmental Impact Statements or Environmental Assessments) at the time the action is being studied. Because the larger scale issues have already been examined, the site-specific studies would primarily focus on the impacts of that particular proposal.

2.2.3 Cumulative Effects Assessment

1. Because the system investment plan was undetermined at the outset of the CEA process, the CEA initially assumed implementation of a reasonable upper limit of navigation improvements to bracket the analysis (i.e., insure that all data necessary to evaluate the potential impacts of actual implementation are available). The reasonable maximum lock size on the Ohio River is governed by channel dimensions, which permit the safe navigation of 15-barge configurations that fit snuggly into a 1200'x110' chamber. Based on this maximum lock size and traffic projections (described in Sections 6 and 9), the reasonable upper limit of lock sizes along the Ohio River was determined to consist of:

– Twin 1200'x110' lock chambers at each dam from Olmsted through Robert C. Byrd L&Ds

– A 1200'x110' main lock chamber and a 600'x110' auxiliary lock chamber from Racine through Emsworth

2. Based on the public input, where public is defined as other federal and state agencies, tribes, non-government organizations (NGOs), and individuals and on technical evaluations, ten "Valued Environmental Components" (VECs) were identified as pertinent to this study for the CEA. Those VECs are:

- Water and Sediment Quality
- Fish
- Mussels
- Riparian/Floodplain Ecological (islands, terrestrial, wetlands, soils/geology, floodplains/hydrology, protected species)
- Air Quality
- Health and Safety
- Recreation
- Transportation
- Socioeconomics
- Cultural Resources

3. The CEA process closely follows the 11-step process provided in CEQ's 1997 Guidance Document "Considering Cumulative Effects Under the National Environmental Policy Act." The process outlined by CEQ groups the 11 steps into three assessment phases as follows:

- Scoping
  - Identify the significant cumulative effects issues associated with the proposed actions and define the assessment goals
  - Establish the geographic scope for the analysis
  - Establish the time frame for the analysis
  - Identify other actions affecting the resources, ecosystems, and human communities of concern

- Describing the affected environment
  - Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to changes and capacity to withstand stress
  - Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds
  - Develop a baseline condition for the resources, ecosystem s, and hum an communities

- Determining the environmental consequences
  - Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities
  - Determine the magnitude and significance of cumulative effects
  - Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects
  - Monitor the cumulative effects of the selected alternative and adapt management

4. The effects on VECS due to the following types of actions are considered in this assessment:

- Construction of new Corps facilities
- Tow traffic patterns and changed tow operating practices
- Operation and Maintenance practices
- Moving cargo by alternative means
- Reasonably Foreseeable Future Actions by others:
  - actions by others that occur only because there is an efficient navigation system ("but for" actions)
  - actions by others that could occur regardless of the Ohio River navigation system
  - natural disasters
  - regulatory environment.

2.3 REPORT ORGANIZATION

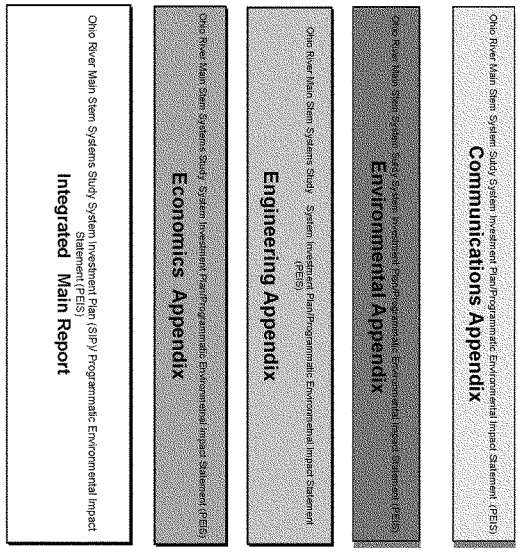
1. This document integrates material usually found in the Main Report and documentation required by the National Environmental Policy Act of 1969 (NEPA), or in

other words, is an integrated report. This structure differs from many of the navigation reports completed before this one, including the Interim Feasibility Report: J.T. Myers and Greenup Locks Improvements. In the past the Corps has opted to segregate the Main Report from the environmental documentation, usually an Environmental Impact Statement, and different color paper was used to distinguish the two report components. NEPA material in this report is not distinguished by a different colored paper; however, sections required specifically by NEPA regulations are marked with a star (*) in the Table of Contents and are provided in Table 2.2. Although there is no format specified by regulation for an integrated report, integration of NEPA documents with other agency reports is encouraged (40 CFR 1500.4(o), 1506.4, 1502.10 – 1502.18). This report structure is viewed as beneficial in comparison to the traditional style as it reduces work efforts and paperwork and should tend to keep report preparation costs down. This format is encouraged by Corps regulations

2. This report systematically presents the study findings relating to development of the System Investment (Sustainability) Plan and all associated environmental analyses. The study process and team participants (agencies and organizations) are described below in this Section. Section 3 lists pertinent reports applicable to all phases of this current study, including the prior Interim Reports on Greenup and Myers Locks and Dams and Ecosystem Restoration, as well as pertinent earlier navigation and environmental reports for the Ohio River projects. Section 4 describes the historical development and current status of the Ohio River navigation system. Section 5 concentrates on the affected environment considered for this study, including adjacent land areas. Section 6 describes the problems and needs for both navigation and environmental sustainability of the Ohio River. Section 7 describes the Public Involvement activities for all phases of this study and how this process impacted the study analyses. Section 8 describes the formulation and determination of "Without-Project Conditions" for several future scenarios of navigation traffic on the Ohio River along with ecosystem sustainability under the WOPC. Sections 9 and 10 address the formulation and determination of WPC plans for the same traffic scenarios as well as formulation of ecosystem sustainability alternatives. Section 11 contains public comments and resolution of those comments as reflected in this report. Section 12 completes the report with findings and recommendations for additional studies.

3. Because of the detail required in a study of this type, and the need to address issues to various audiences, the Draft Report includes four appendices (Economics, Environment, Engineering and Communications) to supplement the SIP Main Report and PEIS. **Figure 2-2** shows these volumes in a pictorial illustration.

FIGURE 2-2
System Investment Plan Report Organization



2.4 STUDY PLAN FORMULATION PROCESS

1. The formulation process used to develop the SIP/PEIS was in accordance with the Corps six-step planning process specified in Engineering Regulation (ER) 1105-2-100 (USACE 2000a: http://www.usace.army.mil/inet/usace-docs/eng-regs/er1105-2-100/toc.htm). As mentioned earlier, this study does not result in the recommendation of any project for authorization; therefore, detailed site-specific plan formulation at any site will be deferred until follow-on site-specific feasibility or other studies. However, the same basic plan formulation process will be followed. This process provides for systematic response to problems and needs that relate to planning (Federal) objectives and pertinent state and local concerns. Essential to this process is consideration of the uncertainty in predicting parameters critical to the formulation and evaluation process. An example of such a critical parameter for a navigation study is future demand for water transportation. An example for environmental sustainability is impacts of future introductions of invasive non-native species. The six steps comprising the plan formulation process for this study are briefly described in sections 2.4.1 through 2.4.6.

2.4.1 Identify Problems and Opportunities.

1. Problems are existing or future undesirable conditions, whereas opportunities refer to attainable and desirable conditions to strive for. Based on these needs or desired conditions, measures are identified to address problems and attain opportunities. Planning objectives are defined and the necessary constraints that may limit the range of viable solutions are identified. The past performance of the ORS has been used as a guide to project potential future problems. The history of the ORS is described in Section 4 and the Environmental Setting of the study area is described in Section 5. Problems and Opportunities are outlined in Section 6. The major planning objectives derived from the problems and opportunities include: ensuring future navigability, improving navigation efficiency and enhancing environmental sustainability.

2.4.2 Inventory and Forecast Critical Resources.

1. Starting with existing conditions, the future status of critical navigation resources is forecast under five scenarios for the most likely future over the 60-year period of analysis. Uncertainty in system demand for water transportation was addressed by developing several future waterway traffic "scenarios" that incorporate different predictions for shipments of coal, the primary commodity moved on the Ohio River. The rationale behind these scenarios and the resulting predictions of waterborne commerce on the Ohio River are contained in Section 8. Uncertainty in the reliability of system components was addressed by engineering reliability analysis. Reliability issues do not define separate scenarios, but are treated probabilistically within each traffic demand scenario. Reliability is also discussed in Section 8.

2. Ten categories of environmental resources (referred to as Valued Environmental Components or VECs) were considered for cumulative effects. Historic and current conditions for each VEC are presented in Section 5 of this report. Forecasts of reasonably foreseeable future conditions and discussions of sustainability are summarized in Sections 6 (Ohio River Problems, Needs and Opportunities) 8 (Ohio River Mainstem Without-Project Condition Assessments), and 9 (Identification of Mainstem Ohio River With-Project System Investment Plans). Detailed assessment of cumulative effects for each of the ten VECs are in the Environmental Appendix, Cumulative Effects Assessment Report.

2.4.3 Formulate Alternative SIPs For Each Traffic Forecast Scenario.

1. Alternative System Investment Plans for navigation investments were formulated by first identifying "measures" to address problems and realize opportunities. As previously described, measures include maintenance, operational efficiency and low cost structural activities, and new lock construction. Structural measures involve construction activities; non-structural involves either low cost construction or operational policies that focus on processing traffic more efficiently. After measures are identified, they are assessed and either dropped from consideration or carried forward for inclusion in one or more alternatives. The same alternatives are formulated for each traffic scenario. The initial step is development of the "without-project" condition, defined as the most likely future conditions at Ohio River mainstem locks and dams without federal investments in high cost maintenance or new lock construction. To improve upon the without-project

SIPs, the high cost maintenance and new lock construction requiring Congressional authorization are considered in "with-project condition" SIPs. The formulation of without-project SIPs is described in Section 8; with-project SIPs are formulated in Section 9.

2. Ecosystem sustainability alternatives were developed by the project team, independent of navigation alternatives, using two sources: the previously authorized Ecosystem Restoration Program (ERP) authorized in 2000 and group discussions with regional aquatic and terrestrial resource experts. See Section 3.2 for more information on the ERP. Sessions were convened to identify actions needed to improve long-term sustainability of ecological resources. The only constraint was to accept that the system is highly modified and will remain so (i.e. it isn't reasonable to return the river and floodplain to predevelopment conditions; however, the system is amenable to further modifications that may affect the resource either positively or negatively). The effort was to be forward looking only, i.e., to consider what can be done in the future. Instructions to the groups were to think only about the resource and to not consider other constraints such as who would take the actions, how or when actions would be implemented, or who would pay for the actions. Ecosystem sustainability needs are the same under all traffic scenarios as sustainability needs were not expected to vary among those scenarios.

2.4.4 Evaluate Alternative SIPs For Each Traffic Scenario.

1. Alternative plans are evaluated to assess future levels of economic, engineering, environmental, and social impacts and outputs. The primary criteria for evaluation of navigation investments are net economic benefits for the nation, referred to as "National Economic Development" (NED) benefits. This process is followed for both the without- and with-project SIPs. Important differences in the levels of these parameters are described and appraised. Evaluations are performed using the Ohio River Navigation Investment Model (ORNIM), developed by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for the Corps of Engineers specifically for the evaluation of alternative Ohio River navigation system investments. This model consists of a suite of four modules that integrate economic, engineering and environmental considerations to the greatest extent possible.[4] Details of the ORNIM model are provided in the Economics Appendix. Plans are carried forward and compared to one another. The best plans for the SIPs for the without- and with- project conditions are carried forth for evaluation. Evaluations are described in Sections 8 and 10 for the without- and with-project navigation SIPs, respectively.

2. Without-project ecosystem sustainability alternatives include those needed actions that could be implemented without additional congressional authority. With-project ecosystem sustainability alternatives add those measures that may require additional authorization by congress, are appropriate for implementation by other agencies, or are likely to incur high costs for planning and implementation. The primary criteria for evaluation of ecosystem alternatives are relative contributions toward restoring ecological functions and attaining long-term resource sustainability. Without-project ecosystem

[4] Engineering considerations are linked through the Lock Risk Module (LRM), economic considerations through the Waterway Supply and Demand Module (WSDM), and environmental through the Navigation Predictive Analysis Technique module (NAVPAT). Finally, the Optimizer module in ORNIM assists in finding the best plan across our 19 lock and dam sites and across time.

sustainability and with-project sustainability alternatives are described in Sections 8 and 9, respectively.

2.4.5 Determine the SIP For Each Traffic Scenario.

1. For each traffic scenario, the set of maintenance, operational efficiency and low cost structural and new lock construction measures that maximize NED benefits is identified. Ecosystem sustainability evaluations do not vary among traffic scenarios so that the same set of measures are preferred. Sections 8 and 10 describe and compare the evaluations for the Without- and With-Project SIPs, respectively, for economic and ecosystem components.

2.4.6 Identify Final SIP and Near Term Activities To Be Implemented

1. The plan with the greatest net economic benefit consistent with protecting the nation's environment is termed the NED plan. The SIP or set of measures that maximize NED benefits in consideration of all five traffic scenarios are considered and that set of measures that best address the whole range of traffic scenarios is identified as the Final SIP. Activities that must be started in the near term to accommodate those measures identified for early in the analysis period are identified for budgeting purposes. Ecosystem measures are considered and included in the Final Combined SIP as appropriate. Further efforts toward implementation of ecosystem sustainability measures may be in the form of "sustainability-focused" mitigation for site-specific impacts or may require non-federal cost sharing partners for feasibility studies and implementation.

2. High cost modernization investments identified as economically justified in this study are not meant to be final recommendations for congressional implementation. Rather, the key point is the identification of a priority list (or blue-print) of modernization needs and the timing when such or similar investments are likely justified, not the specific nature of the investment. Details of the modernization projects will be worked out in follow-on site specific feasibility studies. Feasibility studies are required to confirm or adjust basic assumptions made in this study as to the range of modernization alternatives to consider at each site, allow for more intensive engineering studies that refine the concept-level costs, and to update if necessary economic and environmental data, all of which could have a material bearing on the recommended plan. Finally, the findings in this study are adequate and essential in determining what projects to budget for feasibility study and when those studies should be started.

3. Examples of activities that may be implemented as a result of this study include studies required for structural measures, construction of low-cost structural features, or implementation of operational procedures. The Final SIP and near term actions are described in Section 12. Because ecosystem sustainability alternatives did not vary among traffic scenarios, there was no need to conduct analyses similar to those for navigation SIPs.

2.5 STUDY PARTICIPANTS

1. ORMSS participants are grouped into four major categories, with sub-categories as shown below. The technical study team includes Corps Districts, consulting architect/engineering firms, and universities. Independent Technical Review teams were developed corresponding to the primary study disciplines, namely plan formulation, economics, engineering, and environmental. Within several of these teams, sub-groups of reviewers with very specialized areas of expertise were developed to review specific products. Resource agency and navigation interests were consulted throughout the study for input and comments on work progress. Study oversight was provided by a committee of management staff from the Great Lakes and Ohio River Division (LRD) and the four river districts (Huntington, Louisville, Pittsburgh, and Nashville). The head of this Oversight Committee was the Chief of Planning, LRD.

2.5.1 Technical Study Team

1. This SIP/PEIS is the product of a multi-discipline team of Corps and non-Corps study team members. The three Districts with Ohio River projects within their jurisdictions served as the lead with ample help from navigation and environmental consultants, resource agencies and non-governmental organizations, and navigation industry partners. Study execution involved numerous meetings and communication as described in Section 7 of this report. The major team members are noted below for each category.

Production Team - Ohio River Districts:
U.S. Army Engineer District, Louisville
U.S. Army Engineer District, Huntington
U.S. Army Engineer District, Pittsburgh

Study Team Navigation Design Consultants:
INCA Engineers (Bellevue, WA)
Black & Veatch Engineers (Overland Park, KS)

Study Team Economics and Transportation Consultants:
Center for Transportation Analysis, Oak Ridge National Laboratory
Tennesse Valley Authority
Marshall University
Carnegie Mellon University

Study Team Environmental Consultants:
The Mangi Environmental Group, Inc.
Gulf Engineers and Consultants
Parsons Engineering Science, Inc.
Woolpert, LLP
Environmental Impact Training

Study Team Cultural Resources Consultants:
Gray and Pape (Cincinnati, OH)
Hardlines: Design & Delineation (Columbus, OH)

2.5.2 Resource Agency Interests and Environmental Non-Government Organizations

1. Resource agencies and Environmental Non-Governmental Organizations (NGOs) were involved throughout this study by representation on the Interagency Working Group (IWG). The IWG consisted of approximately 40 members representing federal and state agencies with responsibilities for environmental management, as well as several NGOs. The Corps environmental team (including team members from the environmental consulting firm, Woolpert, Inc. and their sub-contractors), met three to four times annually with the IWG. These one to two day joint meetings generally included information dissemination and updates related to the status of the CEA study, status reports on specific research projects, and working sessions on specific topics. Additional details on this working arrangement can be found in the Environmental Appendix. The agencies represented on the IWG are listed below.

U.S. Fish and Wildlife Agency Field Offices in:
Cookeville, Tennessee
Bloomington, Indiana
Elkins, West Virginia
Marion, Illinios
Ohio River Islands National Wildlife Refuge
Reynoldsburg, Ohio
State College, Pennsylvania
Frankfort, Kentucky
Fisheries Group in Marion, Illinois

Other Federal Agencies:
US Environmental Protection Agency
US Geological Society

State Natural Resources' agencies:
Kentucky Dept. of Fish & Wildlife Resources
Illinois Dept. of Natural Resources
Indiana Dept. of Natural Resources
Ohio Dept. of Natural Resources
Pennsylvania Fish and Boat Commission
West Virginia Dept. of Natural Resources

State Historical Preservation Officers:
Kentucky
Illinois
Indiana
Ohio
Pennsylvania
West Virginia

Other Resource Organizations:
Ohio River Sanitation Commission (ORSANCO)
Non-Governmental Organizations (NGOs)
The Nature Conservancy
Sierra Club
American Rivers
Ohio River Foundation

Navigation Interests
Inland Waterways Users Board (established by Water Resources Development Act of 1986)
The Association for Development of Inland Navigation in America's Ohio Valley (DINAMO), whose Board of Directors include:
Secretary, West Virginia Department of Transportation
Special Assistant to the Governor, Commonwealth of Kentucky
American Waterways Operators (AWO)
Huntington Navigation Advisory Committee
Waterways Association of Pittsburgh
Port of Pittsburgh Commission

2.5.3 Independent Technical Review and Quality Control

1. Independent Technical Review (ITR) is a procedure followed by the Corps to ensure overall quality of a variety of products ranging from planning studies to construction projects. The ITR process is a key part of the Quality Control (QC) of study products. All ITRs involve review by qualified independent personnel not affiliated with the development of the product being reviewed for the purpose of confirming the Corps studies are done in accordance with clearly established professional principles, practices, codes and criteria. For this study, the overall ITR team consisted of sub-groups tasked to review study products produced by a specific team due to the complexity and range of issues. The ITR process supplemented the frequent interactions among study participants referred to as the Product Delivery Team (PDT) and the PDT's review of various products and all report materials. For example, the team leaders of the Economics, Environmental, and Engineering teams reviewed this volume to ensure consistency with the corresponding technical report appendices.

2. The overall ITR process was overseen and coordinated by the U.S. Army Engineer Nashville District (LRN). Oversight of and guidance for the entire study, including production and ITR, was led by the U.S. Army Engineer Great Lakes and Ohio River Division (LRD) located in Cincinnati, Ohio through an Oversight Board (OSB). The Oversight Board was comprised of senior leaders from the Huntington, Louisville, Nashville, and Pittsburgh Districts in addition to senior leaders in the Division office. Teleconferences between the OSB and the PDT were held monthly. At key decision points in the study the OSB and PDT held face-to-face meetings.

3. Independent Review Teams were selected for each of the five disciplines involved in this study, specifically Engineering, Economics, Environmental, Plan Formulation, and Real Estate. The ITR team members included Corps team members having the appropriate expertise to conduct an adequate ITR from throughout the Corps of Engineers. Nashville District and other Corps districts not involved in production of the study conducted much of the ITR. Several topics of the economic analysis required review by special expertise

available only outside of the Corps and the ITR team was expanded to include non-Corps members. Two Corps guidance documents addressing the ITR process that were issued during the latter stages of this study are Engineering Circular (EC) 1105-2-2005, Planning-PEER REVIEW OF DECISION DOCUMENTS, 31 May 2005, and EC 1110-1-105, Engineering-INDEPENDENT TECHNICAL REVIEW, 31 December 2004. The former presents a framework for establishing the appropriate level and independence of review and when and how review by peers outside of the Corps should be assigned. This study follows the spirit of these guidance documents as demonstrated by the external review of economic products, integration of the IWG for environmental issues, and involvement of multiple Corps Districts in all other aspects of the report.

4. A list of the organizations and individuals involved in ITR is shown below and in **Table 2-4**. External experts from outside the Corps were used to review several of economic analyses and reports. The affiliation of these experts are also noted below.

U.S. Army Engineer District, Nashville (Overall Lead, Environmental, and Engineering Design and Cost)
U.S. Army Engineer District, Mobile (Plan Formulation)
U.S. Army Engineer District, Tulsa (Plan Formulation)
U.S. Army Engineer District, New England (Enginering Reliability)
U.S. Army Engineer District, Louisville and Pittsburgh (Office of Counsel)
John Burns of John Burns Assoc. (Economics-Overall)
Mike Bronzini of George Mason University and Karl Pavlovic of DOXA, Inc. (Ohio River Navigation Investment Model-ORNIM)
Janet Skees of Skees Inc. (Economics-Capacity Analysis and Traffic Management)
Steve Fuller of Texas A&M University (Economics – Traffic Demand Forecasts)
Jim Corbett of the University of Delaware (Economics-Transprotation Rates and Willingness to Pay [Elasticities])

5. In addition to this formal ITR, non-navigation stakeholders were involved throughout the study. At the outset of the study, the environmental team established an Interagency Working Group (IWG) made up of State and Federal natural resource agencies and regulatory personnel. Later in the process non-governmental organizations were also represented in the IWG. The IWG met periodically throughout the study to identify issues to be addressed, provide input to the study process, help determine effects, and review results. Although not a part of the formal ITR team, the reviews provided by the IWG were especially valuable to the PDT.

TABLE 2-4
Independent Technical Review Team Functions

Team	Review Responsibilities	Applicable Report Volumes
Engineering	Engineering Data, Reliability Functions, Maintenance Schedules and Costs, New Lock Costs	Engineering Appendix
Economics	Lock Capacities for Existing and New Locks, Traffic Forecasts, Ohio River Navigation Investment Model (ORNIM), Economic Analyses of Maintenance and New Lock Plans, Traffic Management Evaluations	Economic Appendix and Attachments
Environmental	Cumulative Effects Assessment, System Investment Plan/Programmatic Environmental Impact Statement	SIP/PEIS, Environmental Appendix and Attachments
Plan Formulation	Overall Main Report Organization and Content, Plan Formulation Process, Policy Compliance	SIP/PEIS
Real Estate	Real Estate Issues	SIP/PEIS & Engineering Appendices

2.6. INNOVATIVE APPROACHES AND METHODS

1. Traditional navigation planning measures used by the Corps have focused on delineating economic benefits and costs for infrastructure maintenance and navigation improvements. Criticism of these measures have centered on the minimal attention given to risk and uncertainty in the planning analysis (Hammond and Weekly 2005). Risk and uncertainty issues are associated with navigation traffic forecasting, development of proactive schedules for routine maintenance and periodic major rehabilitation of locks and dams, delineation of the environmental effects of single projects in a multi-project system, and enhancement planning for the sustainability of key resources and ecosystems.

2. In a departure from traditional planning measures, the Corps has incorporated several innovative approaches in the ORMSS effort to address and reduce risk and uncertainty over the planning period. Examples of innovative approaches include the generation of environmentally-based traffic demand forecast scenarios, the procurement and analysis of engineering component reliability data for the lock and dam infrastructure, the incorporation of non-structural measures in plan formulation and evaluation, and the development of a state-of-the-art navigation investment model that integrates economic and engineering data along with selected environmental data (Hammond and Weekly 2005). Further information on these approaches follows:

- Five traffic demand forecast scenarios were developed over the planning period to 2070. These scenarios were based on traditional forecasts for basic commodity

groups moved on the river, along with environmentally-driven forecasts for utility coal and sorbent materials (lime and limestone) for flue gas desulphurization. Three alternative regulatory futures relative to air quality management were incorporated in the scenarios along with two economic forecasts based on a survey of the utility industry. These five scenarios, which are assumed to bracket the risk and uncertainty of the forecasts, provide a range of navigation traffic demand for each year in the planning horizon. This range provides the opportunity for more robust and time-sensitive planning for the navigation infrastructure.

- Engineering reliability data surveys were conducted on the key components and overall structural conditions of the existing locks and dams. Based on these data, probability-based component degradation functions and event trees were developed and used to forecast the structural performance of major components of the infrastructure. The forecasts were then used to determine time-sensitive needs for maintenance, major rehabilitations, and lock improvements (Rife, et al. 2005).

- Non-structural measures include those navigation traffic-management schemes that could be utilized to increase the operational efficiency of the navigation system. Such measures can be considerably less expensive than the costs associated with size increases for selected main and auxiliary locks. Further, these measures can be blended with proactive maintenance measures and scheduled major rehabilitation efforts. Traditional navigation planning studies have not routinely included non-structural measures in the analyses. However, at this time for the Ohio River navigation system, these measures will provide operational, economic, and environmental benefits.

- The Ohio River Navigation Investment Model (ORNIM) was developed as a tool to facilitate the integration of information involving probability-based forecasts of lock performance, multiple scenarios of traffic demand, and a host of investment options over the planning horizon. The output from ORNIM identifies the optimal set of investment options (e.g., proactive maintenance, major rehabilitation, etc.) for each existing lock over the planning horizon to 2070 (Hammond and Weekly 2005). ORNIM itself is based on sound economic theory and state-of-the-art computer programming techniques. Systematic usage of ORNIM enables the examination of both individual locks and their combinations in the overall navigation system.

3. Another innovative approach routinely used during the ORMSS involved special efforts to be aware of comparable navigation planning studies; recently-released Corps policies, regulations, and guidelines; new scientific studies on specific topical issues; and emerging themes associated with the NEPA process. The approach involved gathering information on the subject, discussions of the information by the study team, and, as appropriate, incorporation of the requirements or information into the ORMSS. Illustrations of the above-listed categories include:

- Consideration of the National Research Council's review of the Upper Mississippi/Illinois Waterway (UMR/IWW) draft navigation study (National

Research Council 2001). This review provided a basis for incorporating non-structural measures into the ORMSS.

- Review of 2001 guidance from Corps Headquarters to the UMR/IWW study team to include environmental sustainability improvements in every alternative (Rife, et al. 2005). This review provided the impetus for adding improvements to ecosystem sustainability as an objective for the ORMSS. Further, the achievement of ecosystem sustainability was stressed in the Chief of Engineers' seven Environmental Operating Principles (U.S. Army Corps of Engineers 2002 and subsequent guidance and regulation). In fact, all seven principles were incorporated in this study.

- Review of the National Research Council's book on functions and strategies for management of riparian areas (National Research Council 2002). The scientific and policy information provided the foundation used to identify, predict, and assess cumulative effects on the riparian resources of the Ohio River mainstem.

- In 2003, the Council on Environmental Quality (CEQ) issued a report on modernizing the implementation of NEPA requirements (Council on Environmental Quality, 2003). The use of monitoring and adaptive management (AM) as a follow-on to a NEPA document (e.g., a Programmatic EIS) was encouraged as a new "NEPA model". The review of this report, along with numerous other references related to the use of AM for natural resources and infrastructure projects formed the basis for a recommendation for the establishment of an AM program for the Ohio River mainstem (National Research Council, 2004).

4. The environmental features of the ORMSS included several innovative approaches. First and foremost, a programmatic impact study was conducted for all the actions and resources associated with the mainstem. Cumulative effects assessment (CEA) was the integrating tool for this impact study. The goal of the CEA study was to assess the full direct, indirect, and contributed impacts of maintenance, major rehabilitation, and further modernization of the navigation system on resources, ecosystems, and human communities along the mainstem. The analyses addressed the accumulation of meaningful impacts to valued environmental components (VECs) from the actions related to the navigation system in concert with actions and impacts from other past, present, and reasonably foreseeable future actions (RFFAs) by the Corps and others.

5. During the early stages of the detailed planning for the CEA study, it was determined that there were no precedent-setting studies or comprehensive examples for large rivers involving waterway navigation. Accordingly, several new and innovative approaches were developed. Summary information on these approaches follows:

- To provide a planning framework for the CEA study, the CEQ's 11-step CEA process was applied at both a general planning level and a detailed level for identified VECs. Steps 1 to 4 relate to scoping, Steps 5 to 7 to describing the affected environment, and, Steps 8 to 11 to determining the environmental consequences (Council on Environmental Quality, 1997).

- To achieve coordination across the large study area with numerous institutional boundaries and overlapping responsibilities of various federal and state agencies, a 40-person Interagency Working Group (IWG) was formed to provide input and reviews during the conduct of the CEA study. The IWG met three to four times per year at various locations throughout the study area.

- To maintain flexibility due to numerous pragmatic uncertainties associated with performing the study, a multi-component continuous scoping process was developed. The components were comprised of a Project Delivery Team (PDT), oversight board (OB), IWG, scoping meetings (agencies and general public), use of questionnaires, and use of an informational website.

- To consider multiple past, present, and RFFAs in relation to their individual and cumulative effects on the selected VECs, RFFA matrices were developed to delineate cause-and-effect relationships between the actions and 22 selected VECs and their subcomponents. A total of 87 RFFAs were identified and divided into six categories: navigation investment actions, other Corps actions, "but for" actions (actions that would not occur "but for" the existence of the navigation system), actions by others, natural disasters, and regulatory environment. Each listed RFFA was characterized in terms of its anticipated effects, its anticipated time of occurrence, probability of occurrence, and location on the river. Finally, the importance (high, medium, or low) of each RFFA relative to cumulative effects on each VEC or subcomponent was described. As a result, it was determined that RFFA matrices are valuable tools for facilitating a systematic process for considering and evaluating RFFAs in a CEA study. RFFA matrices force the users to consider multiple future actions that may impact a given VEC or subcomponents. Also, completed RFFA matrices provide a documented basis for "scoping" RFFAs and determining which should be addressed in a more detailed manner. Further, information extracted from completed RFFAs can be utilized to summarize a number of key points related to a CEA study. Examples include time periods when given RFFAs are expected to occur; their occurrence probabilities; the settings on or along the river where the given RFFAs are expected to occur; the RFFAs with anticipated negative effects, positive effects, and combinations thereof; and the importance categories for the RFFAs.

- To assess the cumulative effects of multiple actions on environmental sustainability (ES) of the selected VECs, an analysis of environmental sustainability (AES) was developed. This method combines the effects of actions on hierarchical indicators of ES so that sustainability classes can be designated. The AES approach was comprised of four parts: (1) identification of "common effects" on the VEC or subcomponent thereof from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of indicators of ES for the VEC or subcomponent thereof, and their tiered grouping, as appropriate; (3) description of the "connections" between the common effects (and related High and Medium importance RFFAs) and the indicator groups; and (4) assignment of a "bottom line" sustainability category for the VEC or subcomponent, based on considering the past, present and future conditions. The ES categories included "not sustainable",

"marginally sustainable", and "sustainable". Specific ES definitions were developed for each VEC or subcomponent. Lessons learned from this approach were: (1) it encourages the user to think about the connections between multiple actions and indicators in both a relative and holistic manner, thus encouraging the synthesis of a large body of information; (2) it could be strengthened with quantitative information on each action, indicator, and tiers of indicators; however, in the absence of time-related information on each part, a qualitative discussion of the connections can still be useful; and (3) the structured framework of the approach can be useful for identifying current and future monitoring, mitigation, and sustainability needs, and for planning AM programs, as appropriate.

- To identify VEC-based actions that could be used to improve sustainability, the PDT utilized groups of experts to delineate sustainability needs for aquatic and riparian/floodplain resources (Swor, et al., 2005). The results of this "expert elicitation" were then considered in the development of several ES measures that could be incorporated in the SIP. In addition, the findings of an authorized ecosystem restoration program for the Ohio River were used in the formulation of these ES measures (U.S. Army Corps of Engineers, 2000).

6. During planning and conduct of the CEA study, several specific research efforts, surveys, or data needs were identified in relation to the selected VECs. Accordingly, another innovative approach involved the following special efforts related to the CEA study:

- Study of various engineering and hydraulic factors related to Ohio River locks and dams, along with fish swimming velocities of 44 target species, to ascertain upstream fish passage opportunities at the mainstem dams.

- Study of winter habitat types used by fishes in the Smithland and Belleville navigation pools, and comparison of the results between the downstream and upstream pools.

- Study of fish movement in the Ohio River based on fish tagging and tag return data; a survey of fish community structures within lock chambers in relation to tailwater fish communities, along with short-term movement patterns of targeted species at the Winfield locks and dam on the Kanawha River; and a description of the results of creel surveys (recreational angling) in the tailwaters of Ohio River locks and dams.

- Compilation of basic literature and historical data on mussel species in the navigation pools of the Ohio River mainstem, (including the preparation of an Ohio River Mussel Database CD); and a survey of glochidial infestation on Ohio River fish species.

- A study of recreational usage of the Ohio River mainstem.

- A focus group study of recreational trends on the Ohio River.

- Collection of data on bottom substrates, bathymetry, and structure for navigation pools in the Ohio River mainstem -- the results were used in the Navigation Predictive Analysis Technique (NAVPAT) modeling.

- Several other databases have been developed from these studies; they include a spatial database for the fish tagging studies, angler use surveys, and NAVPAT field data. These databases provide resource information that can be used for a variety of purposes by various stakeholder groups.

7. The final innovative approach to be noted is that this integrated report has been developed to present the SIP. The report includes interwoven information related to navigation traffic demands, engineering reliability analyses of the existing lock and dam infrastructure, cumulative effects on various resources and ecosystems, analyses of the benefits and costs related to time-sensitive maintenance and rehabilitation of the infrastructure, and identification of high priority ecosystem sustainability needs for aquatic and riparian/floodplain resources. Further, the information is presented so as to include the components of a programmatic EIS as required under NEPA. Finally, the integrated main report is supported by multiple appendices, including those related to traffic demand forecasts, engineering reliability analyses, the comprehensive CEA study, outputs of the ORNIM model, a communications plan, and others.

Selected References

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Rife, V. L., Benedict, J. M., and Swor, C. T., "Overview and Status of the Ohio River Mainstem System Study", presented at the International Association for Impact Assessment (IAIA'05) Theme Forum entitled "The Ohio River Mainstem Systems Study (ORMSS) – A Case Study Illustrating Innovative Approaches", May 30-June 3, 2005, Boston, Massachusetts.

Swor, C. T., Canter, L. W., Rieger, D., Hollins, E., and Harrell, L., "Analysis of Environmental Sustainability Needs for the Ohio River Mainstem System Study", presented at the International Association for Impact Assessment (IAIA'05) Theme Forum entitled "The Ohio River Mainstem Systems Study (ORMSS) – A Case Study Illustrating Innovative Approaches", May 30-June 3, 2005, Boston, Massachusetts.

U.S. Army Corps of Engineers, "Environmental Quality – Policy for Implementation and Integrated Application of the U.S. Army Corps of Engineers (USACE) Environmental Operating Principles (EOP) and Doctrine", ER 200-1-5, October, 2003 Washington, D.C.

U.S. Army Corps of Engineers, "Planning Civil Works Projects under the Environmental Operating Principles", EC 1105-2-404, May, 2003, Washington, D.C.

U.S. Army Corps of Engineers, "USACE Environmental Operating Principles and Implementation Guidance", March 26, 2002, Washington, D.C.

U.S. Army Corps of Engineers, "Integrated Decision Document and Environmental Assessment, Ohio River Ecosystem Restoration Program", 2000, Great Lakes and Ohio River Division, Cincinnati, Ohio.

SECTION 3
PRIOR STUDIES AND REPORTS

The Ohio River Mainstem System Study (ORMSS) that reviewed all lock projects on the Ohio River mainstem as a system began in 1995. Prior to that point, this study concentrated on the Uniontown {now J.T. Myers} project with a 1200' main chamber and a 600' auxiliary chamber that resulted in the Uniontown Reconnaissance Report. Corps review of that report set the stage for subsequent studies, stating:

> The Corps must take a "systems look" to properly address the level of investments needed to continue to provide a viable navigation system ***on the Ohio River Mainstem***. ... the entire Ohio River Mainstem navigation system should be carefully reviewed, but your primary emphasis for this study should concentrate on the lower portion of the river.

Thus, ORMSS is a Master Plan for long-term needs along the entire 981-mile Ohio River for a 60-year planning horizon. The Project Study Plan for ORMSS also allowed for the development of interim authorization (feasibility) documentation for near term system projects, if appropriate, prior to completion of the final report due to time requirements. These reports are summarized in Sections 3.1 and 3.2. Section 3.3 contains a list of other pertinent reports and summaries.

3.1 INTERIM FEASIBILITY REPORT: J.T. MYERS & GREENUP LOCKS IMPROVEMENTS (APRIL 2000)

Based on industry input and supporting investigations and analyses that documented critical needs at J.T. Myers and Greenup Locks and Dams early in preparation of the SIP, an interim feasibility report was initiated in 1998 that focused those facilities. A Notice of Intent to Prepare an Environmental Impact Statement for the Ohio River Main Stem System Study was published in the Federal Register on October 21, 1998. The J.T. Myers and Greenup Locks Improvements Interim Feasibility Report was completed in April 2000 and recommended similar improvements at each site that included:

- Extending the shorter 600' locks (the land-side chambers) to 1200' length. (These are nominal dimensions, i.e. a *1200'-chamber* means that a 1200-foot long tow can be accommodated in the chamber.)
- Installation of a Miter Gate Quick Changeout System (MGQCS). The MGQCS provides for significantly faster repairs to the lock gates in the future at these two sites, whenever gate repairs are required.

These improvements were authorized by the Water Resource Development Act of 2000 (WRDA 2000). Both projects are currently in the design phase and initial construction has begun at J.T. Myers.

3.2 OHIO RIVER ECOSYSTEM RESTORATION PROGRAM (OCTOBER 2000)

During preparation of the J.T. Myers and Greenup Locks Improvements Interim Feasibility Report, the need of and support for an ecosystem restoration program tailored to the unique characteristics of the Ohio River and its associated floodplain became a recurrent theme. Because of the apparent need for such a program, a component of the ORMSS became a study to determine whether an ecosystem restoration program specifically tailored to the Ohio River and associated floodplain corridor should be recommended for authorization. A Notice of Intent to Prepare an Environmental Assessment for Proposed Authorization of an Ecosystem Restoration Program was published in the Federal Register on June 9, 2000. This study was conducted independent of navigation aspects of the ORMSS. A second interim report, the Ohio River Ecosystem Restoration Report, was prepared and the program authorized in WRDA 2000. The integrated Decision Document and Environmental Assessment provide the following conclusions and recommendations for authorization of an Ohio River Ecosystem Restoration Program:

- A comprehensive, managed ecosystem restoration program is needed for the Ohio River corridor consistent with current law and Corps policy.
- A recommendation for authorization of a multi-year program, with maximum Federal funding of $10 million annually, for each of the first five years, and $15 million annually for the remainder of the program.
- The creation of a partnership composed of representatives from government resource agencies, universities, and other environmental concerns, for monitoring, evaluating and managing the Ohio River ecosystem.
- A corridor-wide ecosystem needs assessment and strategy, or Program Implementation Plan, would be developed initially to refine ecosystem goals and prioritize restoration efforts.
- Implementation of site-specific projects to accomplish program goals.

Non-Federal sponsors would fund 35 percent of site-specific project first costs and 100 percent of operation, maintenance, repair, rehabilitation, and replacement. This program has not been funded to date and is now a candidate for de-authorization.

3.3 OTHER PERTINENT REPORTS

Table 3-1 summarizes major decision documents pertinent to the ORMSS SIP/PEIS. The two most recent studies are for Major Rehabilitation projects at Markland Locks and Dam (April 2000) in the Louisville District and for Emsworth Locks and Dams in the Pittsburgh District (July 2001). These rehabilitation projects are on-going. Work at Markland includes replacement of lock gates and hydraulic machinery in the main chamber, whereas work at Emsworth involves replacement of all pre-World War II vintage

vertical lift dam gates with new hydraulic lift structures and the scour protection downstream of both dams. These rehabilitations are designed to extend the useful life of the affected components by at least fifty years.

TABLE 3-1
LIST OF PRIOR MAJOR REPORTS PERTINENT TO THE ORMSS
SYSTEMS INVESTMENT PLAN REPORT (sheet 1 of 5)

Document Title	Date	Produced by	Summary
Lower Ohio River Navigation Feasibility Study, IL-KY (Mouth to Cumberland River) Locks and Dams No. 52 and 53 and Final Environmental Impact Statement	Nov-85	Louisville District	Recommended a new project near Olmsted, IL (Ohio River Mile 964.4) to replace Locks and Dams 52 and 53. The new project will be comprised of a gated dam with navigable wicket section and twin 1200'x110' lock chambers. Comstruction scheduled to be complete in 2013.
Ohio River Mainstem Study, Gallipolis Interim Navigation Feasibility Report and Emvironmental Impact Statement	Feb-81	Huntington District	Recommended new 1200'x110' and 600'x110' lock chambers. Construction completed in 1995. Project now R.C. Byrd L/D.
Report on Replacement-Emsworth, Dashields and Montgomery Locks and Dams	Apr-71	Pittsburgh District	Analyzed alternatives for rehabilitation and replacement for the three upper-most projects on the Ohio River. Recommendation never processed.
OTHER REPORTS SUPPORTING ORMSS			
Expert Elicitation for Concrete Monoliths at Emsworth, Dashields and Montgomery L/Ds, Ohio River	Sep-00	Pittsburgh District	Assessed Concrete Condition and Probabilities of Failure at Emsworth, Dashields, and Montgomery
Ohio River, Emsworth, Dashields, and Montgomery Locks and Dams, Condition Report	Jul-00	DLZ for Pittsburgh District	Detailed Condition Summary for Emsworth, Dashields, and Montgomery
ORMSS - 100% Submittal Constructibility and Cost Estimate (Analyses) for Prototype Alts. (DACW27-95-C-0126)	May-98	INCA Engineers (Bellevue, WA) for the Louisville District	Descriptions, drawings, constructn schedules, & cost estimates for 9 configuratns of F/E systems. Constructibility evaluations.
ORMSS - 100% Submittal Conceptual Design of Emsworth, Dashields, and Montgomery Locks and Dams, Ohio River	Sep-97 & Jan-98	INCA For the Pittsburgh District	Cost estimates for alternatives with 1200' & 600' locks and twin 600' locks at these sites.

TABLE 3-1
LIST OF PRIOR MAJOR REPORTS PERTINENT TO THE ORMSS SYSTEMS INVESTMENT PLAN REPORT (sheet 2 of 5)

Document Title	Date	Produced by	Summary
Lower Ohio River Navigation Feasibility Study, IL-KY (Mouth to Cumberland River) Locks and Dams No. 52 and 53 and Final Environmental Impact Statement	Nov-85	Louisville District	Recommended a new project near Olmsted, IL (Ohio River Mile 964.4) to replace Locks and Dams 52 and 53. The new project will be comprised of a gated dam and twin 1200'x110' lock chambers.
Ohio River Mainstem Study, Gallipolis Interim Navigation Feasibility Report and Environmental Impact Statement	Feb-81	Huntington District	Recommended new 1200'x110' and 600'x110' lock chambers
Report on Replacement-Emsworth, Dashields and Montgomery Locks and Dams	Apr-71	Pittsburgh District	Analyzed alternatives for rehabilitation and replacement for the three upper-most projects on the Ohio River. Recommendation never processed.
OTHER REPORTS SUPPORTING ORMSS			
Expert Elicitation for Concrete Monoliths at Emsworth, Dashields and Montgomery L/Ds, Ohio River	Sep-00	Pittsburgh District	Assessed Concrete Condition and Probabilities of Failure at Emsworth, Dashields, and Montgomery
Ohio River, Emsworth, Dashields, and Montgomery Locks and Dams, Condition Report	Jul-00	DLZ for Pittsburgh District	Detailed Condition Summary for Emsworth, Dashields, and Montgomery
ORMSS - 100% Submittal Constructibility and Cost Estimate (Analyses) for Prototype Alts. (DACW27-95-C-0126)	May-98	INCA Engineers (Bellevue, WA) for the Louisville District	Descriptions, drawings, constructn schedules, & cost estimates for 9 configuratns of F/E systems. Constructibility evaluations.
ORMSS - 100% Submittal Conceptual Design of Emsworth, Dashields, and Montgomery Locks and Dams, Ohio River	Sep-97 & Jan-98	INCA For the Pittsburgh District	Cost estimates for alternatives with 1200' & 600' locks and twin 600' locks at these sites.

TABLE 3-1
LIST OF PRIOR MAJOR REPORTS PERTINENT TO THE ORMSS SYSTEMS INVESTMENT PLAN REPORT (sheet 3 of 5)

Document Title	Date	Produced by	Summary
Impacts of Diversion of Traffic Off Of the River System Due to Unreliable Lock Service at The Upper Ohio River Navigation Projects Emsworth, Dashields and Montgomery Locks and Dams	Jul-00	Gannett Fleming, Inc. for the Pittsburgh District	Estimated the potential for lost jobs and wages due to long-lock closures at Emsworth, Dashields and Montgomery locks and dams.
ORMSS Field Inspection Report of all L&D Facilities on the Ohio River (Pittsburgh, Huntington & Louisville Districts)	1996-1997	CELRP; inspections by a core group of engineers from the Huntington, Louisville, and Pittsburgh Districts.	Details visual inspection of facilities at each L&D plus interviews with Lockmasters & projects' O&M Leaders. Provides numerical ratings for various L&D components, and photos of conditions at each L&D.
Impacts on Traffic Volumes due to Modernization of Emsworth, Dashields and Montgomery Locks	Jan-01	Tennessee Valley Authority for the Pittsburgh District	Evaluated potential barge movements that would be induced with construction of new 1200'x110' lock chambers at each of the Emsworth, Dashields, and Montgomery projects.
OTHER OHIO RIVER NAVIGATION REPORTS			
Great Lakes and Ohio River Navigation Systems Commerce Reprot, 2002	2002	Huntington District Navigation Planning Center	Intervening year statistical updates to biennial Ohio River and Great Lakes Navigation Systems
OHIO RIVER NAVIGATION SYSTEM -- 1999 Statistical Supplement (also 1997, 1994 and 1990)	1999	Huntington District Navigation Planning Center	Intervening-year statistical updates to the biennial Ohio R. Nav. System Report (1998)

TABLE 3-1
LIST OF PRIOR MAJOR REPORTS PERTINENT TO THE ORMSS
SYSTEMS INVESTMENT PLAN REPORT (sheet 4 of 5)

Document Title	Date	Produced by	Summary
Ohio River Basin Comprehensive Survey in 14 volumes	Aug-69	Ohio R Basin Survey Coordintg Comm.; Departments of Agriculture; Army; Commerce; Health, Education & Welfare; Interior; Federal Power Commission, Various States	A basin freamework study covering economics, water supply, pollution, F&W resources, navigation, flood control, etc.
OTHER OHIO RIVER ENVIRONMENTAL REPORTS			
Ohio River Section 7 Report	Dec-04	Louisville, Huntington and Pittsburgh Districts	
Ohio River Navigation Project, Final Environmetnal Impact Statement	Jan-80	Huntington District	
Draft Environmental Impact Statement on Commercial Sand and Gravel Dredging Operations in the Allegheny (Mile 0 to Mile 69.5) and Ohio (Mile 0 to 40) Rivers	1/1/2005 (projected)	Pittsburgh District	
Hydroelectric Power Development in the Upper Ohio River Basin	Sep-88	Federal Energy Regulatory Commission	Final Environmental Impact Statement prepared by the FERC to evaluate potential environmental impacts of up to 19 hydropow er projects in the upper Ohio River Basin. The recommendation w as to allow for up to sixteen of these possible projects to be constructed and operated.

TABLE 3-1
LIST OF PRIOR MAJOR REPORTS PERTINENT TO THE ORMSS SYSTEMS INVESTMENT PLAN REPORT (sheet 5 of 5)

Document Title	Date	Produced by	Summary
OHIO RIVER MAINSTEM SYSTEM STUDY ENVIRONMENTAL STUDIES			
Winter Habitat Used by Fishes in Smithland Pool and Belleville Pool, Ohio River	Dec-03	J. Garvey, S. Welsh, K. Hartman, et.al. (Southern Illinois Univ.)	
Fish Passage Study Conducted for ORMSS - Distribution of Mussles and Fish Within the Ohio River	Jan-03	G. Watters, T. Cavender, C. Myers, M. Kibbey, V. Gordon, B. Pittinger, T. Pohlman, (The Ohio State Univ)	
Upstream Fish Passage Opportunities at Ohio River Mainstem Dams	Dec-03	B. Knights, J. Wlosinski, J. Kalas, S. Bailey, (USGS)	
Ohio River Mainstem Context Study	Sep-01	D. McVarish, D. Berg, R. Carlisle, W. Mulligan (ed by Greenhorne & O'Mara)	
Fish Passage Issues Associated with Ohio River High-Lift Dams	Apr-04	C. O'Bara (WV DNR)	
NAVPAT Application to the Ohio River Mainstem System Study and the Evaluation of NAVPAT Habitat Relationships	Jan-06	US Army Corps of Engineers	
Project Report for Woolpert Ohio River Recreation	Jan-04	T. Shaw, J. Minser (Institute for Policy Research, Univ of Cincinnati)	

SECTION 4
OHIO RIVER NAVIGATION SYSTEM

This section provides an overview of the Ohio River Navigation system – its geography, history of Federal development, and commodity movements and statistics focusing on the period 1970-2000. Navigation along the mainstem Ohio River and throughout the Ohio River Basin is described.

4.1 DESCRIPTION OF OHIO RIVER NAVIGATION STUDY AREA

1. The navigation study area includes the entire mainstem Ohio River, which extends 981 miles from the junction of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, to near Cairo, Illinois where the Ohio flows into the Mississippi River. Year-round navigation is provided on the Ohio River by 20 locks and dams (soon to be 19 with the completion of Olmsted and subsequent removal of L/Ds 52 and 53) and periodic maintenance dredging. This river forms the backbone of the navigation system within the entire Ohio River basin, referred to as the Ohio River Navigation System, or ORS (**see Figure 4-1**). The ORS comprises more than 2,600 miles of commercially navigable waterways. Within this basin, the Corps has also constructed and operates and maintains 82 reservoirs, primarily for flood control, water supply, low flow augmentation and recreation. Releases from these reservoirs during periods of drought can sustain navigation during drought periods. The basin comprises 204,000 square miles and is home to over 31.5 million people (2000 census), and encompasses all or portions of fourteen states, including Alabama, Georgia, Kentucky, Indiana, Illinois, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Pittsburgh, Cincinnati, Columbus, Indianapolis, Louisville, and Nashville are the region's largest cities. Locks and dams also provide year-round navigation on seven tributaries to the main stem Ohio River (Allegheny, Monongahela, Kanawha, Green, Kentucky, Cumberland and Tennessee Rivers). These tributaries are not part of this study.

2. The topography of the basin varies from rugged mountains to flat plains. The Appalachian Mountains dominate the eastern portion. West of these mountains and south of the Ohio River, the landscape contains considerable local relief, which gradually modifies to rolling plains through most of Kentucky and Tennessee. North of the Ohio River, broad valleys with only minor relief extend from southwestern and central Ohio through central Indiana into southern Illinois.

FIGURE 4-1
Locks and Dams of the Ohio River Navigation System

4.2 HISTORY OF FEDERAL DEVELOPMENT OF THE OHIO RIVER

1. Federal involvement in improving the Ohio River for commercial navigation began in 1824, when Congress directed the Corps to find a method of removing sandbars and snags. The desired channel depths to be attained by this clearing and snagging program were 3 feet and 30 inches for the lower and Upper River reaches, respectively. This depth was deemed adequate for vessels at the time, consisting of steamships, keelboats, and flatboats. By 1870, William Milnor Roberts proposed that a six-foot navigation pool along the entire Ohio River would be necessary to accommodate future navigation. It was estimated that sixty-six locks and dams would be required to provide this channel. The River and Harbor Act of 1875 provided funds for the construction of a movable dam 4.7 miles downstream of Pittsburgh at Davis Island, also known as Lock and Dam 1. Federal canalization of the Upper Ohio River for 6-foot navigation was started in 1877 with the start of construction of Davis Island Lock and Dam. Completed in 1885, the project consisted of one lock chamber 600' long and 110' wide (600'x110') and a wicket dam which allowed traffic to navigate the river without proceeding through the lock in high flows. This was the only federally constructed facility in the nineteenth century. One other lock (78' wide) was constructed with funding provided by private sources and the

city of Louisville in the Portland Canal that skirted the "Falls of the Ohio" at Louisville. The six-foot channel was never realized.

2. By 1908, Locks and Dams 2 through 6 were constructed extending down to Ohio River mile 30. However, by 1900, coal barge tows requiring nine-feet of draft were already operating on the Ohio River and a nine-foot channel depth for the entire river gained popularity. Subsequent to a recommendation by the Board for Rivers and Harbors in 1906, the River and Harbor Act of 1910 authorized a 9-foot slack-water navigation project for the Ohio River, with projects consisting of movable (wicket) dams and a single lock chamber 600'x110'. The Act originally provided for the construction of 54 locks with movable dams and for the widening of the Louisville-Portland Canal at Louisville, Kentucky, and the construction of a new lock in the canal. This plan was modified with certain substitutions and eliminations under authorities of the River and Harbor Act of 18 July 1918 and 30 August 1935. The original Ohio River "project", when completed in 1929, consisted of 50 lock and dam structures and the Louisville-Portland Canal and canal lock and provided reliable channel depth of 9 feet. During this period, Ohio River traffic grew substantially, increasing from 10 million to 20 million tons between 1923 and 1925. **Table 4.1** chronicles the construction history of the original Ohio River project (three left columns).

3. During construction of the original Ohio River project, it was recognized that fixed, non-navigable dams had some advantages over the movable (navigable) dams, particularly in maintaining permanent pools for the convenience of navigation and in providing better conditions for industrial development along the river banks. Accordingly, the River and Harbor Act of 18 July 1918 provided "That the Secretary of War is hereby authorized to modify the project for the improvement of the Ohio River in accordance with the report submitted in House Document 1695, 64th Congress, 2nd Session. The House Document recommended replacement of original Ohio River Locks and Dams 1 and 2 by the Emsworth Locks and Dams (where the dam was comprised of two sections separated by Neville Island) and dual locks. The original Emsworth project included fixed weir dam sections. The dams were reconstructed in 1937 with a low sill and vertical lift gates to provide a deeper and more stable pool at Pittsburgh. Dashields Locks and Dam was constructed under the 1918 authority to replace original Lock and Dam No. 3.

TABLE 4.1
History of Ohio River Lock and Dam Construction

Original Lock and Dam #[1]	Miles Below Pittsburgh[1]	Navigation Commenced	High Lift Locks & Dam(s)	Miles Below Pittsburgh	Navigation Commenced
1 (Davis Island)	4.7	1887	Emsworth	6.2	1921
2	9.0	1906			
3	10.9	1908	Dashields	13.3	1929
4	18.6	1908			
5	23.9	1907			
6	29.3	1904	Montgomery	31.7	1936
7	36.5	1914			
8	46.4	1911	New Cumberland	54.4	1956
9	56.1	1914			
10	66.2	1915			
11	76.9	1911	Pike Island	84.2	1963
12	87.0	1917			
13	95.8	1911			
14	114.0	1917	Hannibal	126.4	1972
15	129.1	1916			
16	146.6	1917	Willow Island	162.4	1972
17	167.5	1918			
18	179.9	1910			
19	192.2	1916			
20	202.5	1917	Belleville	203.9	1968
21	214.6	1919			
22	220.9	1919			
23	231.4	1921	Racine	237.5	1967
24	242.4	1919			
25	260.7	1922			
26	278.5	1912	R.C. Byrd	279.2	1993
27	301.0	1923			
28	311.6	1915			
29	319.9	1916			
30	339.4	1923	Greenup	341.0	1959
31	359.3	1920			
32	382.6	1925			
33	405.1	1921			
34	434.1	1925	Meldahl	436.2	1962
35	451.0	1919			
36	461.0	1925			
37	483.2	1911			
38	501.3	1924			
39	529.6	1912	Markland	531.5	1959
41	606.8	1927	McAlpine	606.8	1961
43	630.2	1921			
44	660.3	1926			
45	703.0	1928	Cannelton	720.7	1971

46	752.9	1928			
47	772.5	1927	Newburgh	776.1	1975
48	804.1	1921			
49	845.0	1927	J.T. Myers	846.0	1975
50	876.8	1929	Smithland	918.5	1979
52	938.9	1928			
53	962.6	1929	Olmsted		2013[2]

[1] Lock and Dam Mileposts for Original Navigation Project taken from Ambler, C.H., A History of Transportation in the Ohio Valley, Greenwood Press, 1931, pp. 421-422.
[2]Projected Completion Date.

Montgomery Locks and Dam, comprised of a fixed, gated dam was built under the same 1918 authority to replace Locks and Dams 4, 5, and 6. The sizes of the locks at these chambers were the same; 600' x 110' (main chamber) and 360' x 56' (auxiliary chamber). Congress also specifically authorized the Gallipolis Locks and Dams in the River and Harbor Act of 39 August 1935. That project replaced the three lower locks and dams on the Kanawha River and Locks and Dams Nos. 24, 25 and 26 on the Ohio River. It consisted of a single high-lift, gated dam and dual chambers, 600' x 110' and 360' x 110'. By 1937, with construction of Emsworth, Dashields, Montgomery and Gallipolis locks and dams, the total number of locks on the Ohio River reduced to 46.

4. Ohio River traffic in the early 1900's was highly dependent upon coal movements from Pittsburgh to New Orleans. Due to heavy declines in this traffic, which was diverted to steel plants in the Upper Ohio Valley, Ohio River traffic dropped to its lowest level in 1917, 4.6 million tons. Then, transportation demands of World War I severely overburdened existing overland transportation systems and river traffic increased. The original canalization project was completed in 1929. Ohio River tonnage rebounded to over 22 million tons by 1930. This waterway spurred economic growth and assisted the rapid nationwide mobilization during World War II. Sustained post-war expansion of the national economy increased the use of all types of commodities carried on the river. Oil and gasoline products moved upriver while coal moved downriver in great quantities. This rapid growth in traffic exceeded the government's ability to increase lock capacity and by the 1950s serious delay problems had become obvious. The original 600-foot lock chambers built during the days of paddleboats and wooden barges were obsolete and could not handle large modern tows in a single lockage.

4.3 RECENT OHIO RIVER LOCKS AND DAMS IMPROVEMENTS

1. As increased navigation costs began to affect the region's economy, plans were formulated beginning in the 1950s to modernize the original navigation system. The improvement plan developed called for the replacement of earlier low-lift structures with a lesser number of high-lift locks. The modernized structures provide higher-lift dams, with longer pool-reaches between projects, and larger lock dimensions. Modernization of the Ohio River Navigation System began in 1954 with construction of Greenup Locks and Dam, a structure with a 30-foot lift, a 1200 by 110-foot Main lock, and a 600 by 110-foot Auxiliary lock. The modernization program envisioned 19 modern high-lift projects, and this system will finally be realized after construction of Olmsted and the decommissioning

of Locks and Dams 52 and 53, tentatively scheduled for 2009. The construction history of the modern high-lift projects is shown in **Table 4-1** (rightmost three columns). The specifications for these projects are listed in **Table 4-2**. A map of the current system was show in **Figure 2.1**.

2. Improvements on the Ohio River Mainstem continue today at Robert C. Byrd Locks and Dam (formerly Gallipolis) located just upstream of Huntington, West Virginia; Olmsted Locks and Dam on the lower Ohio River, see **Table 4-1**). The last lock modernization project was completed in January 1993 at Robert C. Byrd Locks, where two new locks measuring 1200 by 110 feet and 600 by 110 feet replaced the outdated 600'x110' main chamber and 360'x110' locks. The Olmsted project at river mile 964.4, which will provide a modern structure to replace Locks and Dams 52 and 53, will consist of twin 1200 by 110-foot locks and a new dam with submersible gates to allow tow passage over the dam during higher flow conditions. With completion of Olmsted, the number of Ohio River mainstem projects will be reduced from 20 to 19. The McAlpine project at river mile 606.8 replaced the old 600' Auxiliary Lock with a new 1200' chamber -- providing this site with twin 1200 by 110-foot chambers.

3. The Ohio River is a vital transportation artery for the Ohio River basin states, as well as a large number of other states due to its interconnections with the Mississippi River, the Great Lakes, and U. S. coastal ports.

TABLE 4-2.
Ohio River Lock Specifications

Lock & Dam Project Name	RiverMile (downstream of Pittsburgh)	Year Operational			Year Rehabilitated			Chamber Sizes	
		Main	Aux.	Dam	Main	Aux.	Dam	Main	Aux.
Emsworth	6.2	1921	1921	1922	1984	1984	1984	600x110	360x56
Dashields	13.3	1929	1929	1929	1990	1990	1990	600x110	360x56
Montgomery	31.7	1936	1936	1936	1989	1989	1989	600x110	360x56
N. Cumberland	54.4	1956	1959	1961				1200x110	600x110
Pike Island	84.2	1963	1963	1965				1200x110	600x110
Hannibal	126.4	1972	1972	1975				1200x110	600x110
Willow Island	162.4	1972	1972	1973				1200x110	600x110
Belleville	203.9	1968	1968	1969				1200x110	600x110
Racine	237.5	1967	1967	1970				1200x110	600x110
R.C. Byrd	279.2	1993	1993	1937			2000	1200x110	600x110
Greenup	341.0	1959	1959	1962				1200x110	600x110 b
Meldahl	436.2	1962	1962	1964				1200x110	600x110
Markland	531.5	1959	1959	1964				1200x110	600x110
McAlpine	606.8	1961	1921	1964		1965		1200x110	1200x110 a
Cannelton	720.7	1971	1971	1971				1200x110	600x110
Newburgh	776.1	1975	1975	1975				1200x110	600x110
J.T. Myers	846.0	1975	1975	1975				1200x110	600x110 b
Smithland	918.5	1979	1979	1979				1200x110	1200x110
L&D No. 52	938.9	1969	1928	1929		1983	1984	1200x110	600x110 c
L&D No. 53	962.6	1980	1929	1929		1982	1984	1200x110	600x110 c

a The new 1200'x110' chamber at McAlpine opened in 2009.

b Auxiliary locks at J.T. Myers and Greenup L/Ds will be extended to 1200'.

c Olmsted L&D, now under construction at river mile 964.6, will replace both L&D 52 and 53. This new facility will have 2 identical chambers, both of size 1200'x110' with completion by 2013.

4.4 CURRENT STATE OF THE OHIO RIVER

1. Existing conditions on the Ohio River mainstem may be described as follows:

A large canalized river open year-round, consisting of 20 pools formed by 20 locks and dam structures. (After the completion of Olmsted L&D in 2008, which replaces L&Ds 52 and 53, there will be 19 pools and 19 locks and dam structures.) By *canalized* we mean that the original free-flowing river was controlled, starting over 100 years ago, into a series of relatively flat pools ("canals") for purposes of maintaining year-round navigation. The locks are open 24 hours a day, except during periods when a chamber is closed due to weather or for inspection and maintenance/repair work. A minimum navigation channel of 9-foot depth and 300-foot width is provided with use of dredging and snagging (tree and log removal).

The current geometry of the river, as modified by the higher pool levels of the modernized dam system, generally provides for safe navigation of commercial tows as long as 1200' long x 108' wide. A typical large jumbo-hopper-barge tow consists of fifteen 195'x35' barges, plus a towboat of varying dimensions, resulting in a tow of about 1170'x105'. Occasionally, tows on the lowermost reaches of the Ohio, below Smithland L&D, operate in a double-wide configuration of 30 barges (5 long x 6 wide), typical of the larger tows on the lower Mississippi River. During winter months, these 6-barge-wide tows can navigate over the navigable wickets of Dams 52 and 53 (and after 2009 the wickets at the new Olmsted L/D). Such tows cannot navigate through these wickets during the drier months, when they must use the locks at L&D 52 and 53. Locks at Olmsted will also be used during low flow periods

In terms of age and size, the locks and dam facilities may be classified into 3 broad groups:

The 60+ year old upper three structures (Emsworth, Dashields, and Montgomery L&Ds) just downstream of Pittsburgh PA. These 3 locks each have one 600'x110' Main chamber and a 360'x56' Auxiliary chamber. Fifteen-barge tows must be processed in double-cuts through the Main chamber, while tow sizes are limited to five-cuts in the small Auxiliary chamber.[1] The condition of these old structures, together with the inefficiently-small lock sizes, are major concerns. In the year 2010, 14 of the 40 lock chambers will be over 50 years old, and 24 will be between 30 and 50 years old.

The 13 modernized lock and dam structures constructed between 1954 and 1979, plus Byrd L&D which has new locks completed in 1993. This includes all the locks from New Cumberland downstream to J.T.Myers, a distance of 791.6 miles. Each of these newer locks has a 1200'x110' Main lock chamber and a 600'x110' Auxiliary chamber. The 1200' long Main chamber allows 15-barge tows to lock through in a single operation, while smaller tows or other vessels usually use the Auxiliary chambers. These newer locks and dams are spaced about 60 miles apart, on average, and replaced a series of about 50 old lower-lift structures built around the turn of the century.

[1] Tows too large for a lock chamber are broken into smaller pieces, or cuts. Each cut is processed through the chamber individually. A tow that must be broken into two pieces is referred to as a double-cut, and its processing through the lock as a double-cut lockage.

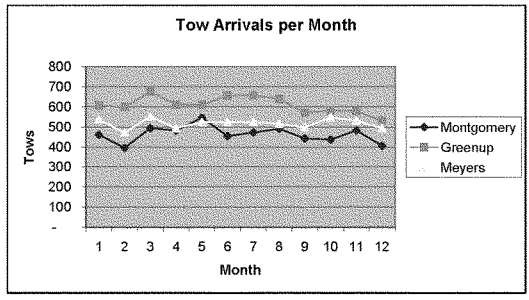
Locks which have two side-by-side 1200'x110' locks. These include Smithland L&D (placed in operation in 1980), McAlpine (placed in operation in 2009) and Olmsted L&D (now under construction).

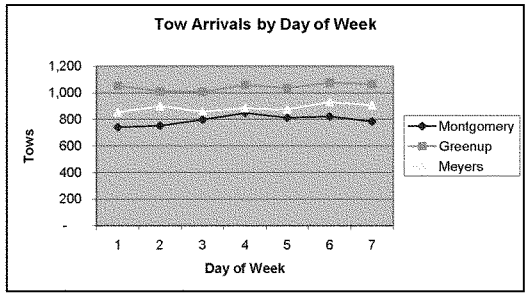
Tow arrival patterns at all locks are uniformly distributed throughout the year. As shown in **Figure 4-2** for Montgomery (upper river), Greenup (middle river), and Myers (lower river) L/Ds, traffic is relatively constant by month, day of week and even hour of day.

- During normal operations, the main chamber at mainstem projects is used predominantly by large tows and the auxiliary chamber is used by single cut tows of less than 600' in length, recreational traffic, and other smaller vessels like lightboats (tow boats with no barges). (Based on data from 2000-2004, just 13.5% of all recreational vessels and 30.5% of all lightboats used the main chambers at Ohio River locks.) The maximum number of cuts allowed is a single cut through the main chamber and a double cut through the auxiliary chamber except for the upper three projects where, due to smaller size, double cut lockages are allowed at the main chamber and five-cut lockages at the auxiliary. Multiple cut lockages are allowed in the auxiliary chamber during periods of closure of the main chamber.

- The general steps of the lockage procedure for any tow are shown in **Figure 4.3**.

FIGURE 4-2
Ohio River Traffic Patterns





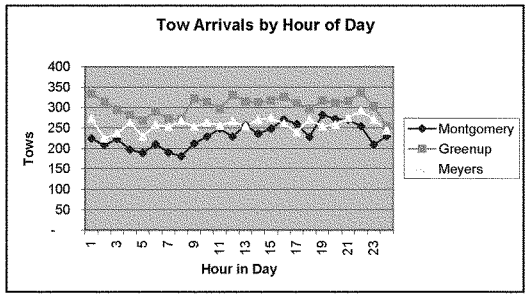
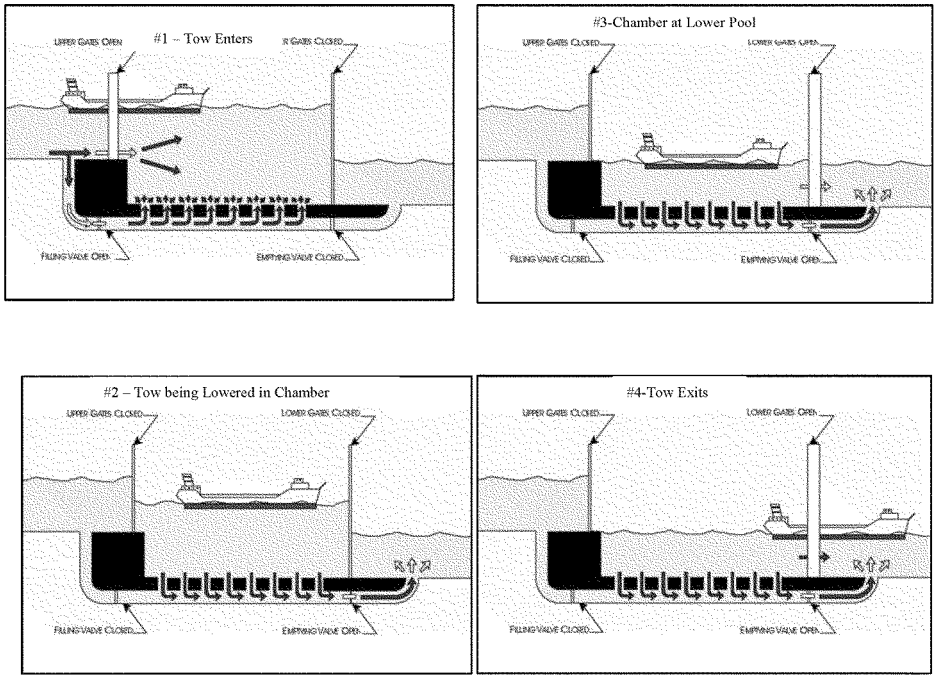


FIGURE 4-3

Lockage Process



2. The typical tow through all locks with a 1200'x110' main chamber consists of fifteen "jumbo" barges (each of dimension 195'x35"). **Tables 4-3, 4-4 and 4-5** describe the types of barge and tanker equipment used on the Ohio River, commodities moved, and average tow sizes and loadings through each project during 1990-2000. For additional details on Ohio River traffic, see Section 5 of the Economics Appendix.

TABLE 4-3
Description of Barge Types on Ohio River

Barge Type	Dimension	Capacity (Ktons)	Typical Commodities
Hopper			
Irregular	135'x27'	867	Aggregates
Standard	175'x26'	1,069	Coal, Aggregates
Stumbo	195'x26'	1,121	Coal
Jumbo	**195'x35'**	**1,669**	**Coal, Aggregates, Ores & Iron**
Covered Jumbo	195'x35'	1,764	Grains, Chemicals
Super Jumbo	245'x35'	2,106	Coal, Aggregates
Giant Jumbo	260'x52'	3,329	Coal, Grains, Aggregates and Coke
Tanker			
Jumbo	195'x35'	1,454	Petroleum Products & Chemicals
147'	147'x52'	1,711	Petroleum Products & Chemicals
175'	175'x54'	2,317	Petroleum Products & Chemicals
264'	264'x52'	2,820	Petroleum Products & Chemicals
290'	290'x54'	3,295	Petroleum Products & Chemicals

Source: COE LPMS Data.

TABLE 4-4
Annual Ohio River Trips and Tonnage by Barge Type
Averaged Over 1990 – 2000

Barge Type	Dimension	Avg. Annual		Percent of Total	
		Trips	Tons*	Trips	Tons
Hopper					
Irregular	135'x27'	3,215	2,004,284	2%	1%
Standard	175'x26'	5,571	4,943,714	4%	2%
Stumbo	195'x26'	8,535	9,428,949	6%	5%
Jumbo	**195'x35'**	**97,691**	**151,960,762**	**72%**	**73%**
Covered Jumbo	195'x35'	7,752	12,002,606	6%	6%
Super Jumbo	245'x35'	390	807,399	0%	0%
Giant Jumbo	260'x52'	869	2,497,370	1%	1%
Sub-Total		124,023	183,645,084	91%	88%
Tanker					
Jumbo	195'x35'	5,005	7,153,370	4%	3%
147'	147'x52'	1,734	2,695,467	1%	1%
175'	175'x54'	643	1,244,841	0%	1%
264'	264'x52'	1,188	2,886,932	1%	1%
290'	290'x54'	3,749	11,405,339	3%	5%
Sub-Total		12,319	25,385,949	9%	12%
Total		136,341	209,031,033	100%	100%

Source: WCSC data
* excludes intra-pool traffic

TABLE 4-5
Average Ohio River Tow Sizes

Project	Total Barges Per Tow	Loaded Barges Per Tow	Tons Per Tow	Tons Per Loaded Barge
Emsworth	6	4	4,845	1,352
Dashields	6	4	5,298	1,327
Montgomery	7	4	5,861	1,375
New Cumberland	9	5	7,901	1,472
Pike Island	9	6	8,667	1,482
Hannibal	11	7	11,099	1,494
Willow Island	11	8	11,527	1,502
Belleville	11	8	11,971	1,508
Racine	11	8	11,482	1,511
R.C. Byrd	11	7	11,481	1,556
Greenup	11	7	10,409	1,585
Meldahl	11	7	11,505	1,603
Markland	10	7	10,702	1,593
McAlpine	10	7	10,678	1,594
Cannelton	11	8	11,916	1,569
Newburgh	11	7	11,058	1,565
J.T. Myers	11	8	12,187	1,606
Smithland	11	7	11,250	1,613
L/D 52	10	6	9,999	1,616

Source: COE LPMS Data.

4.5 WATERWAY DEPENDENT INDUSTRIES IN THE OHIO RIVER BASIN

1. Waterway dependent industries are those industries that realize some advantage for locating alongside a navigable waterway system. The two major advantages are the availability of a large and reliable supply of water for use in the industrial process, and the availability of an efficient and reliable waterway transportation system for the movement of goods into or out-of the facility. The transportation advantage is the advantage of interest to this study, since locks and dam projects are sized and constructed to facilitate waterway transportation. Other location factors, including taxes, labor force, terrain, and rail and road access are also important, but are beyond the scope of this study.

2. The major users of the Ohio River System are the coal industry and the electric generating industry (see **Table 4-6**). While it is likely that both industries would have developed even without a navigable transportation system, it is unlikely that they would have grown to the extent that they have. The reason is that waterway transportation provides a cost-advantage over other modes, which allows coal produced in the area to be competitively priced in a geographically wider market than it would be otherwise. As far back as a hundred years ago, coal produced in the Monongahela River Basin was shipped down-river as far as Oklahoma. In contrast, no coal was delivered overland to these markets. The same is true of the electric generating industry; because of the low transportation cost of waterway shipments, and the multiple sources of coal available via waterway transportation, electric generating costs in the basin are among the lowest in the nation.[1] Electricity produced in the basin can be economically exported to high-cost production areas. Again, the size of the market and the amount of electricity generated would be less without the transportation cost savings provided by the waterway system.

[1] According to the U.S. Department of Energy, Energy Information Administration, average revenue per kilowatt-hour is 5.9 cents for the eight Ohio River Basin states and 6.8 cents for the entire United States. Only six states have lower average revenues than the mean average revenue for the basin states.

TABLE 4-6
ORS Waterway Commodity Traffic, 2001

Commodity		Tons (Millions)
Coal	**Total**	**157.1**
	Steam Coal	130.7
	Metalurgical Coal	10.1
	all else	16.3
Crude Petroleum	**Total**	**0.3**
Petroleum Products	**Total**	**20.2**
Chemicals	**Total**	**10.6**
	Fertilizers	2.8
	all else	7.8
Aggregates	**Total**	**46.7**
	Sand & Gravel	18.4
	Limestone	24.6
	all else	3.7
Grains	**Total**	**18.2**
Ores & Minerals	**Total**	**6.9**
Iron & Steel	**Total**	**11.0**
	Steel Scrap	1.6
	all else	9.4
Others	**Total 8.**	**9**
	Wood Products	0.6
	all else	8.3
Grand Total		**279.9**

3. The markets for coal are electric generating plants, coke plants, other industrial plants such as cement, and export. The electric generating industry dwarfs the other sectors, consuming 911 million tons a year or 87 percent of the one billion tons of coal produced in the U.S. every year. The Ohio River Basin is an important production region and proximity to waterways infers an advantage. Over ten percent of national production came from these large ORB mines in 2001.

4. The electric power industry involves the generation, transmission, and distribution of electricity. Fossil fuels are the most widely used fuel for electricity generation. Coal is the most widely used fossil fuel in the United States, and particularly in the ORB. In fact, the ORB is the U.S. region most dependent upon coal for electric power generation. Fossil fuels are transported to generating plants by rail, river barge, truck, conveyor, and pipeline. Electricity is transmitted from generating plants to consumers by wire. The electric power industry is the largest user of the ORS. In 2001, over 130 million tons of coal and 2.3 million tons of lime were barged to electricity generating plants. These movements represent almost fifty percent of total tonnage transported on the ORS.

5. The electricity industry is an important consumer, as well as a key producer (i.e. owner and operator of coal mines) of coal in the economy. The industry consumes about 87 percent of the over 1 billion tons of coal produced in the country. Of this amount, about 14 percent or nearly 120 million tons moves on the Ohio River system to waterside power plants. The tonnage accounts for about 1 of every 2 tons shipped on the system.

6. Low-cost electricity also attracted energy-intensive industry to the region. Foremost among these are the aluminum and the steel industries, particularly the new electric furnace plants that recycle scrap into steel. The principal input of both industries is electricity, and therefore, the availability of low-cost electricity is a major consideration in location decisions. Other industries dependent upon the ORS as reflected in the commodity movements in Table 4-6 are steel, sand and gravel, petroleum, and chemical plants.

7. There are a number of other waterway dependent industries along the waterway as well that depend on the waterway more for water supply and as an optional transportation mode, and for an occasional barge shipment, rather than for continuous/high volume shipments. These types of plants include mineral processing plants such as zinc, nickel and aluminum plants. Other facilities are highly dependent on the waterway transportation system, but may ship modest quantities on the system. These facilities would include the intermodal ports that provide a wide variety of shipping options to a wide variety of industries and cargoes in order to survive.

8. Additional details on many of these industries are contained in the Economics Appendix.

4.6 OHIO RIVER SYSTEM AND MAINSTEM COMMODITY MOVEMENTS

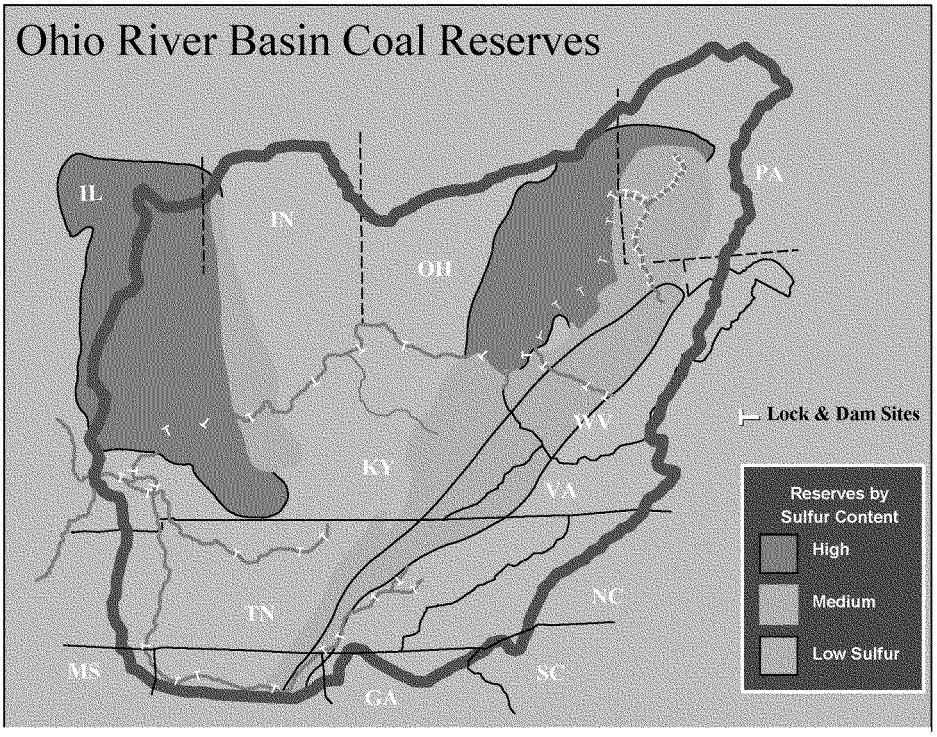
1. Waterborne commerce throughout the Ohio River Basin is made possible year-round in the basin by a series of 60 lock and dam projects spread throughout the Ohio River and its 12 navigable tributaries, a navigation network known as the Ohio River System (ORS) (see **Figure 4.1**). In recent years barges along the ORS have carried approximately 270 million tons of commodities on all navigable rivers within the basin. These commodities are the product of coal mines, petroleum refineries, stone quarries, cement plants, and farms and the raw material for construction companies, steel mills, electric utilities, paper plants, aluminum manufacturers, and chemical companies; the foundation of the region's economy.

2. Ohio River System transportation consists largely of coal and other bulk or raw commodities -- goods with a long "shelf-life" and which are moved efficiently in large volumes. The ORS extends this efficient transportation mode deep into the interior of the North American continent. The availability of this form of transportation, along with the availability of rich deposits of coal (approximately 70 billion tons of demonstrated reserves), have made Pittsburgh, Pennsylvania and Huntington, West Virginia, the second and fourth largest coal ports, respectively, in the United States. **Figure 4.4** is a map of the region's coal reserves consisting of the Appalachian Coal Province (low-medium sulfur content) to the east and the Eastern Interior Coal Province (high sulfur content) to the west.

3. Most of the basin's coal moves to domestic markets -- primarily to the electric utility industry. Over the last 30 years, much of the region's electricity generating capacity has moved away from small streams and large cities to more rural areas along the Ohio River and its system of navigable rivers. Dependable supplies of cooling water and access

to low-cost transportation are the primary attractions. In fact, electric utility companies account for nearly half of system traffic.

FIGURE 4-4
Ohio River Basin Coal Fields

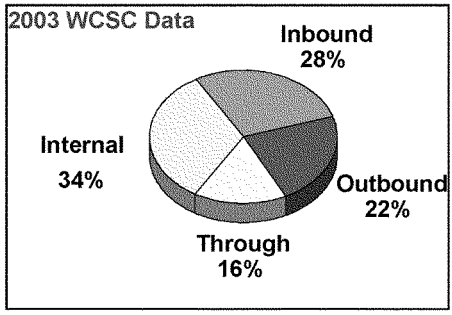


4. The main artery of the Ohio River System is the mainstem Ohio. Approximately eighty nine percent of system traffic moves on the Ohio River (see **Table 4-7**). Between 1950 and 1965, traffic on the mainstem doubled, and then doubled again between 1965 and 1990. Most of this traffic growth was driven by massive investments in waterside coal-fired electric generating facilities that were expanding to accommodate the needs of an expanding economic base. Electric utilities were locating plants along the Ohio River and expanding their existing waterside facilities to take advantage of the river as a source of water supply and for low-cost water transportation of coal. Since 1990, with no growth in coal traffic, the small percent growth in Ohio River traffic has been driven by increases in aggregates, ores and minerals, and iron and steel traffic. Mainstem traffic reached a peak of just under 243 million tons in 2002, total tonnage fell slightly to about 229 million tons in 2003. As can be seen in **Figure 4-5** below, most of this traffic (34 percent) is internal to (i.e. both origin and destination on) the mainstem.

TABLE 4-7
Historic Ohio River System and Mainstem Ohio Traffic
(Million Tons)

Year	ORS	Ohio River	% ORS
1940	51.2	29.5	58%
1950	66.1	48.6	74%
1960	105.3	79.5	75%
1970	163.9	129.6	79%
1980	200.5	160.7	80%
1990	257.8	225.7	88%
2000	271.7	236.5	87%
2004	269.9	239.0	89%
Annual Growth:			
- 1940-04	2.7%	3.4%	
- 1990-04	0.1%	0.1%	
Source: USACE Waterborne Commerce Statistics			

FIGURE 4-5
Inbound, Outbound, Through and Internal Traffic on the Ohio River Mainstem Traffic



Note: Inbound, Outbound and Internal Traffic as defined previously, through traffic has neither origin or destination on mainstem but travels on mainstem for part of trip.

5. The mainstem Ohio River handled about 229 million tons of traffic in 2003, representing about 88 percent of the traffic on the Ohio River System (ORS). The Ohio River handled all of the petroleum fuels moving on the ORS in 2003, and nearly all of the grains, chemicals, ores and minerals, and iron and steel traffic. The mainstem handled a considerably smaller share of the system's coal and coke and aggregates traffic. The commodity traffic distribution in 2003 both for the Ohio River and the ORS are shown in **Table 4-8.**

TABLE 4-8
Commodity Traffic on Ohio River Mainstem and the ORS, 2003
(Million Tons)

Commodity	ORS	Ohio River	Ohio River % of ORS
Coal & Coke	140.9	118.5	84.1%
Petroleum	16.8	16.3	97.0%
Aggregates	47.4	41.7	88.0%
Grains	14.1	13.8	97.9%
Chemicals	11.4	10.3	90.4%
Ores & Minerals	7.4	7.4	100.0%
Iron & Steel	14.3	13.9	97.2%
Other	7.4	6.8	91.9%
TOTAL	259.7	228.7	88.1%

Source: WCSC data

6. Ohio River traffic by commodity group for selected years between 1970 and 2000 is shown in **Table 4-9**. On the mainstem, each of the major commodity groups increased in tonnage between 1970 and 2000, with the exceptions of petroleum fuels and crude petroleum. The completion of major pipeline projects into the ORB diminished the need for waterborne transport of petroleum fuels and crude petroleum. The highest annual growth rates over the 30-year period occurred for shipments in the all others category (principally cement, lime, asphalt and animal feeds); iron and steel; grains; and ores and minerals, followed by aggregates and coal and coke. Chemicals traffic was flat over the 30-year period and petroleum products and crude petroleum diminished, as previously mentioned. Between 1990 and 2000, traffic growth was dominated by iron and steel, ores and minerals, and aggregates, followed by chemicals and all others. Grains and petroleum fuels grew much more slowly over this 10-year span, while crude petroleum and coal and coke traffic diminished.

TABLE 4-9

Historic Ohio River Commodity Traffic,

1970 - 2000

(Million Tons)

						Annual % Growth	
Commodity	1970	1980	1990	1995	2000	1970-00	1990-00
Coal & Coke	59.0	86.1	136.7	130.3	121.8	2.4	-1.1
Petroleum Fuels	15.5	17.7	13.4	13.4	14.1	-0.3	0.5
Crude Petroleum	7.1	0.6	0.5	0.2	0.4	-9.4	-2.9
Aggregates	17.2	21.2	28.7	33.4	38.9	2.8	3.1
Grains	3.6	6.7	10.3	12.0	10.8	3.7	0.5
Chemicals	10.6	11.5	9.3	10.7	10.8	0.0	1.5
Ores & Minerals	3.9	3.2	5.5	6.7	9.1	2.9	5.2
Iron & Steel	4.4	4.1	6.5	10.1	14.3	4.0	8.2
All Others	5.5	9.6	17.0	19.0	18.9	4.2	1.0
TOTAL	126.8	160.7	225.7	235.8	236.5	2.1	0.6

SOURCE: USACE Waterborne Commerce Statistics

7. **Table 4-10** shows total commodity traffic at Ohio River mainstem projects for the period 1970-2000 from the Corps Waterborne Commerce Statistics (WCS). Annual percentage growth rates during this period ranged from 0.3 percent at Dashields to 3.2 percent at Greenup. During the last decade of the century, growth rates remained robust within the middle portion of the river and turned negative at the lower end. Commodity traffic growth was hampered in the 1990s by a substantial drop-off in export coal and grain traffic, the loss of some domestic utility steam coal markets outside of the ORS, and a reduction in the usage and waterborne movement of Illinois Basin and Northern Appalachian coals by electric utilities. The projects most severely affected during the 1990s were the lower river projects. Traffic at the uppermost Ohio River projects remained about the same or slightly lower at Dashields during 1990-2000. The traffic for the more recent 1994-2004 time period from the Corps Lock Performance Monitoring Statistics (LPMS) period is shown as **Table 4-11**. (WCS data vary slightly from LPMS data.) Growth rates are a little more negative on the upper river than the lower, while traffic has remained about the same for the middle third.

TABLE 4-10
Historic Traffic at Ohio River Projects, 1970-2000
(Million Tons)

Project	1970	1980	1990	1995	2000	Annual % Growth 1970-00	Annual % Growth 1990-00
Emsworth	19.6	20.0	21.8	21.6	21.9	0.4	0.1
Dashields	20.2	21.0	23.2	22.8	22.4	0.3	-0.4
Montgomery	17.4	20.4	25.0	25.2	25.2	1.2	0.1
New Cumberland	19.2	23.2	30.4	36.5	34.2	1.9	1.2
Pike Island	19.8	26.4	36.0	43.9	42.3	2.6	1.6
Hannibal	22.4	30.4	36.3	47.9	49.8	2.7	3.2
Willow Island	25.6	31.6	34.5	45.6	47.0	2.0	3.1
Belleville	26.1	32.6	37.0	48.4	50.9	2.3	3.2
Racine	27.0	34.0	38.2	49.0	51.5	2.2	3.0
Byrd	28.9	37.4	42.3	60.3	59.1	2.4	3.4
Greenup	28.7	34.8	56.2	71.0	74.0	3.2	2.8
Meldahl	28.5	34.6	55.2	65.0	64.6	2.8	1.6
Markland	29.4	37.8	53.6	58.8	56.0	2.2	0.4
McAlpine	33.0	41.5	58.4	60.0	55.2	1.7	-0.6
Cannelton	38.1	43.2	62.4	60.5	54.1	1.2	-1.4
Newburgh	32.8	43.9	74.3	73.5	63.0	2.2	-1.6
Myers	34.8	50.3	83.6	85.0	72.0	2.5	-1.5
Smithland	39.1	58.5	91.2	89.9	81.4	2.5	-1.1
L/D 52	45.9	63.0	101.4	98.2	91.8	2.3	-1.0
L/D 53	43.3	53.6	87.8	87.9	85.3	2.3	-0.3
Ohio River	126.8	160.7	225.7	235.8	236.5	2.1	0.6
Ohio River System	163.1	200.5	260.3	263.5	271.8	1.7	0.5

SOURCE: USACE Waterborne Commerce Statistics

TABLE 4-11
1994 - 2004 Ohio River System Traffic by Project
(Ktons)

Project	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Annual Rate 1994-2004
Emsworth	24,272	23,075	23,424	23,201	23,153	23,561	22,334	21,729	23,687	19,211	18,791	-2.5%
Dashields	25,602	24,551	24,765	24,452	24,563	24,528	23,230	22,839	24,516	20,012	19,679	-2.6%
Montgomery	27,313	25,515	27,132	26,480	26,866	26,560	25,974	25,555	26,709	21,093	20,260	-2.9%
New Cumberland	37,272	36,745	36,584	35,564	35,425	33,906	34,062	33,854	35,251	32,189	31,478	-1.7%
Pike Island	43,643	43,309	43,729	41,345	43,027	41,276	41,460	41,682	43,634	39,062	38,912	-1.1%
Hannibal	47,783	42,783	46,596	44,812	47,627	47,258	48,344	49,476	51,200	48,884	50,101	0.5%
Willow Island	45,802	44,534	43,932	42,299	44,766	44,320	45,635	46,975	48,422	46,592	48,123	0.5%
Belleville	48,641	47,122	47,869	45,511	48,688	47,983	49,201	49,243	51,118	49,482	51,380	0.5%
Racine	49,845	48,000	48,933	46,644	49,517	48,646	50,022	50,239	51,764	50,625	52,308	0.5%
R.C. Byrd	56,079	58,649	59,406	56,337	57,855	55,970	57,879	58,108	54,898	53,164	57,775	0.3%
Greenup	68,695	67,573	67,262	69,891	70,635	70,044	71,713	70,563	65,915	62,135	64,502	-0.6%
Meldahl	64,627	63,376	61,270	62,246	63,739	62,784	63,391	63,813	57,771	53,222	55,262	-1.6%
Markland	60,011	57,757	54,680	55,090	55,119	54,850	56,062	55,807	49,625	45,248	50,050	-1.8%
McAlpine	61,943	57,609	53,980	52,823	52,857	54,835	55,790	56,170	51,893	49,482	52,753	-1.6%
Cannelton	64,257	59,513	56,782	56,240	54,386	56,650	55,786	56,653	55,841	54,002	56,888	-1.2%
Newburgh	76,779	72,052	68,300	65,407	64,131	64,509	64,433	66,527	64,200	62,475	67,151	-1.3%
J.T. Myers	85,718	82,108	77,603	76,218	74,151	71,393	72,447	75,290	68,961	62,655	67,880	-2.3%
Smithland	93,337	89,145	85,077	84,931	84,606	82,115	82,610	85,915	79,040	72,305	77,020	-1.9%
L/D 52	101,267	97,467	94,052	94,770	97,695	95,125	94,687	96,715	93,382	87,420	94,954	-0.6%

Source: LPMS Data.

SECTION 5
AFFECTED ENVIRONMENT

This section provides a description of the Ohio River's resources, ecosystems and human communities. Information presented in this section is summarized from material in the Environmental Appendix. For more detailed discussions of each section, refer to the corresponding section in the Cumulative Effects portion of the Environmental Appendix. A brief summation of the material presented in this section begins at section 5.11.

5.1 GENERAL DESCRIPTION

1. The study area includes the mainstem Ohio River, which extends from the junction of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, to near Cairo, Illinois where the Ohio joins the Mississippi River. This area includes 981 miles of commercially navigable channel and a total drainage area of 204,000 square miles. The drainage area encompasses all or portions of fourteen states, including Alabama, Georgia, Kentucky, Indiana, Illinois, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Year-round navigation is provided by a system of 20 locks and dams. Within the Ohio River basin, the Corps has also constructed and operates and maintains 82 reservoirs, primarily for flood control, water supply, and recreation. Releases from these reservoirs during periods of drought aid navigation; however, those benefits are ancillary to authorized project purposes. Navigation is also provided on eight tributaries to the main stem Ohio River (see Fig. 2-1). However, navigable reaches outside the main stem Ohio River are not part of this study.

2. The study area for the ORMSS is defined as the Mainstem Ohio River from Pittsburgh, PA to Cairo, IL. However, in conducting the cumulative effects analysis (CEA), larger areas had to be considered. In fact, the impact area considered in the CEA varies among resource categories according to characteristics of each resource. Therefore, while geographic boundaries for the CEA were generally set the as the Ohio River and Floodplain (i.e., the area most likely to be affected by navigation related actions), we reserved the flexibility to adjust these boundaries as resource conditions dictated. Boundaries for each resource category are described in the CEA Section of the Environmental Appendix.

5.1.1. Endangered Species Consultation

Specific consultation under section 7 for the recommended actions contained in this report was not undertaken[1]. The purpose of this document is to recommend future navigation

[1] Concurrent with the preparation of the ORMSS PEIS, the Lakes and River Division agreed to undertake separate consultation with the US Fish and Wildlife Service under Section 7 of the Endangered Species Act for O&M Actions on the Ohio River Mainstem and its navigable tributaries. The Corps completed and submitted an initial draft Biological Assessment (BA) to the Service in October 2004. After a number of revisions in response to comments from the Service, the Corps completed a final BA and transmitted it to the Service in the spring of 2009. This BA considers all O&M actions undertaken by the Corps and the

needs to maintain a viable system for the next 50 years. The alternatives considered in this report are generic in nature and do not provide enough detail for an adequate assessment. 40 CFR 1502.20 addresses tiering of NEPA documents. A programmatic document is written to "eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review". The Corps determined during preparation of the PEIS, in consultation with the US Fish and Wildlife Service, that Section 7 compliance would be more meaningful if it occurred during development of site specific project reports. The Service agreed to this in the Final Coordination Act Report by stating that "as specific projects and opportunities occur in the future, we expect the Corps to involve the Service, States, and others in determining how each project will or may impact trust resources..." It was agreed that at the site specific level potential impacts to endangered species will be better understood and "ripe for decision".

5.2 AQUATIC ECOLOGICAL RESOURCES

5.2.1 Water Quality and Sediments

See Environmental Appendix, CEA Chapter 3 for an expanded discussion of Water and Sediment Quality.

The following information on conditions of selected water quality indicators has been obtained from several sources. Data included results of more than 60 years of sampling, using a variety of assessment methods, at locations throughout the length of the Ohio River.

5.2.1.1 Historical Conditions

5.2.1.1.1 Dissolved Oxygen

1. Dissolved oxygen (DO) has long been a parameter of primary concern, and this is especially true on the Ohio River. Monitoring and research on DO in the Ohio River dates back to surveys and model development of Streeter and Phelps (1925). DO concentrations in the Ohio River are influenced by several factors, including water temperatures biochemical oxygen demand (BOD), photosynthesis by algae, travel and mixing times of pollutants, and daily fluctuations (Wellner and Dinger 1989). Sufficient dissolved oxygen levels, expressed as mg/L, are critical to support most aquatic life.

2. Historically, DO levels along the Ohio River were depressed by the biochemical oxygen demand (BOD) of raw or insufficiently treated sewage discharges. In 1936, Congressman Brent Spence testified at a congressional hearing on the pollution of navigable waters that "the Ohio River is a cesspool." At that same hearing the State Health Commissioner of Kentucky added "the Ohio River, from Pittsburgh to Cairo, is an open sewer" (USEPA 2003). About 1948, advances in cooperative management, which

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endangered species known or suspected to exist within the geographical area. The BA also developed a suggested list of Reasonable and Prudent Measures that could be implemented by the Corps to minimize potential impacts. With the assumption that these suggested Reasonable and Prudent Measures would be implemented, the BA concluded that O&M activities may affect but are not likely to adversely affect the identified species. A response by the Service is pending.

including signing of the Ohio River Valley Sanitation Commission (ORSANCO)[2] compact, began the process of improving water quality conditions in the Ohio River.

3. Prior to effective wastewater treatment, low DO values were typically recorded downstream from the three major population centers of Pittsburgh, Cincinnati and Louisville. Until the late 1960s and mid 1970s, substantial DO sags occurred downstream of these population centers. During October and November of 1963, for example, HydroScience (1969, cited in US EPA 2003) carefully documented the degree and extent of the DO sag in the Ohio River downstream of Cincinnati (approximately RM 460-480). At the normal bottom of the sag between miles 495 and 500, DO concentrations during this period did not exceed 2.0 mg/l. Zero DO concentrations were recorded at both miles 455 and 505.

5.2.1.1.2 pH/Acidity/Alkalinity

1. Tributary waters to the Ohio River, especially the upper reaches, have historically experienced extreme variations in pH, acidity, and alkalinity. While pH values in excess of pH 9.0 maximum criteria have been observed, values depressed below pH 6.0 minimum criteria were most typical. Also, although massive dumps of acid metal pickling liquors and other episodic events have been documented, chronic acid mine drainage (AMD) from high-sulfur bituminous coal mines were primarily responsible for low pH conditions in the river.

2. As early as 1912, the Pittsburgh Flood Commission identified AMD as a severe economic problem responsible for the corrosion of pipes, pumps, boilers, and navigation structures. By 1914 the U.S. Public Health Service had documented episodic acidification of the Ohio River as far downstream as river mile 172. Data collected by the U.S. Geological Survey and the Pennsylvania Department of Forests and Waters (White 1951) provide a record of conditions between October 1947 and September 1949, when total acidity at Ohio River mile 17 ranged from 5 to 8.6 and averaged 30 mg/l as $CaCO_3$. The pH of the Ohio River ranged from 6.6 to 3.65 and averaged 5.3. Between 1940 and 1965 pH measurements of less than 5.0 (often less than 4.0) were commonly recorded in the upper 100 miles of the Ohio River. Below river mile 100, pH values usually increased gradually to mean values of 7.2 to 7.8 between Cincinnati and Cairo, river miles 463 and 981, respectively. During this same period, unusually high pH records of between 9.0 and 10.0 were occasionally seen in all reaches of the river, probably due to undocumented industrial discharges.

[2] The Ohio River Valley Water Sanitation Commission (ORSANCO), was established on June 30, 1948 to control and abate pollution in the Ohio River Basin. ORSANCO is an interstate commission representing eight states and the federal government. Member states include: Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia." "ORSANCO operates programs to improve water quality in the Ohio River and its tributaries, including: Setting Waste Water discharge standards; performing biological assessments; monitoring for the chemical and physical properties of the waterways; and conducting special surveys and studies."

5.2.1.1.3 Fecal Coliform Bacteria

The presence of fecal coliform bacteria indicates water has been contaminated with human or other animal wastes, generally from the overflow of domestic sewage or nonpoint sources. Fecal coliforms also serve to indicate potential health risk to humans through consumption or contact with water may have been contaminated by pathogens or disease producing bacteria or viruses. Typhoid fever statistics presented by Drake (1931) for the period between 1873 and 1930 show that human health in the ORV was severely threatened by fecal pollution. In 1907, for example, Pittsburgh typhoid fever case and death rates were 1,119.2 and 125.2 per 100,000 inhabitants per year, respectively. Filtration systems for river sources of public water supplies were constructed between 1907 and 1914, and by 1914 typhoid case and death rates dropped dramatically to 64.5 and 15.4 per 100,000, respectively. By 1930 typhoid case and death rates had further declined to 11.2 and 1.5 per 100,000, respectively. However, filtration treated only intake waters. Bacteriological pollution of the river later declined with improved wastewater treatment described in the previous section.

5.2.1.1.4 Turbidity and Total Suspended Solids

1. Turbidity and total suspended solids (TSS) both indicate the amount of solids suspended in water, whether mineral (e.g. soil particles) or organic (e.g. algae). TSS is measured by weight of material per volume of water (mg/L) while turbidity is measured as the amount of light scattered by a water sample, with more suspended particles causing greater light scattering. Turbidity is reported as nephalometric or Jackson turbidity units (NTUs or JTUs), depending on the measuring instrumentation. ORSANCO has no specific standard for TSS.

2. High concentrations of particulate matter in water can cause increased sedimentation and siltation, which, in turn, can damage habitats for fish and other aquatic life. Further, suspended particles provide attachment sites for other pollutants such as heavy metals and bacteria. Turbidity and TSS of the Ohio River are largely influenced by erosion characteristics of native soils and geology. Human activities (including clearing, draining of wetlands, agriculture, and development) accelerate soil loss and runoff to waterways. Qualitative reports from the 19th century describe the Ohio River as naturally clear except for the higher turbidities of the spring "freshes" (periods of flooding). Pearson and Krumholz (1984) note that Mark Twain and others described the Ohio as naturally the clearest of the three major arms of the Mississippi River system.

3. From 1953-1985, ORSANCO observed a decreasing trend in turbidity, coinciding with the construction of numerous flood control reservoirs on major Ohio River tributaries. These im poundments trap sedim ents and releas e clearer water. According to Pearson (1992), the range of turbidities to which Ohio River fish are exposed in m odern tim es is probably not significantly greater than in preh istoric tim es, but the m ean turb idities are higher now.

5.2.1.1.5 Nutrients

1. Nitrogen and phosphorus are nutrients that stimulate growth of algae and aquatic plants that provide food for most other forms of aquatic life. Nitrogen and phosphorous

occur naturally in water. Major sources of these nutrients entering rivers include municipal and industrial wastewater, septic systems, agricultural runoff, and atmospheric deposition. Nitrate and phosphate are the forms of these elements most readily available for plant growth. Normally concentrations of nitrate and phosphate in river water are low because plants rapidly take up both ions (Hynes 1970).

2. There are few data on historic nitrate and phosphate concentrations in the Ohio River. However, considering that virtually no sewage treatment or runoff controls existed prior to the 1970s, it can be concluded that high levels of both nutrients were present in the mainstem and tributaries.

5.2.1.1.6 Sediments

1. The natural bottom substrate of the Ohio River is mainly sand, gravel or clay overlain, especially in near shore or other sheltered areas, with silt and/or organic detritus. In 1971, Mason et al. described the combinations of these materials in different parts of the river as follows:

- Upper river - characterized by many bottom deposits covered by an oily muck with small coal particles interspersed with sand and gravel
- Middle river - predominately a pasty clay overlain with sand, rubble or fine leaf detritus
- Lower river below Louisville - predominately mud overlain with different grades of sand and leaf detritus

2. Fine-grained sediments are usually found at the mouths of tributaries, on riverbanks and near lock and dam structures ORSANCO (1996). Ohio River sediments are generally highly mobile and dynamic because high proportions of surficial bottom materials are replaced with every storm event.

3. Heavy metal contamination in the Ohio River has resulted from various sources, including coal mine drainage (iron and manganese) and industrial activity, particularly the iron and steel industry of the upper Ohio River valley. Bottom sediments are natural "sinks" for many toxic and persistent pollutants that enter waterways. These deposits represent potential sources of contaminants that may reenter the water column through stream scouring, anaerobic release, and bioaccumulation, as well as through dredging for channel maintenance (Youger and Mitsch 1989). Even with increasing control of point and nonpoint pollution sources, sediments contaminated with heavy metals and other pollutants may continue to adversely affect overlying waters and food chains for years (Lyman 1987).

4. Steel mill slag can influence the quality of the Ohio River. Massive slag fills have been used as a foundation material for extensive riverfront industrial developments in the upper ORV (Josephson et al 1949 and USACE 1982 and 1989). Slag has also been used extensively for placement of highway shoulder berms, driveway and parking lot fills, stream bank protection, and as railway grade ballast. Steel mill slags can produce mineralized and extremely alkaline leachates. In the late 1960s, when coal field drainage still significantly acidified the Allegheny and Monongahela Rivers, Shapiro et al (1967) found that the Ohio River became net alkaline after flowing past the steel manufacturing

complexes near Pittsburgh. Koryak et al (2002) proposed that slag leachate products contributed to this large, unexplained, alkalinity load.

5.2.1.2 Recent Conditions and Trends

5.2.1.2.1 Dissolved Oxygen

1. Following passage of the 1965 Federal Water Quality Act, the Ohio River Valley Sanitary Commission (ORSANCO) adopted stream water quality recommendations. In 1970, ORSANCO Pollution Control Standard I-70 made secondary level treatment the minimum requirement for wastewater treatment plants. As a result, BOD effluent loading decreased significantly, even as influent volume continued to grow with population increases. Massive Federal cost sharing construction grants to local authorities from 1972 to 1995 helped support planning, design, and construction of wastewater plants to meet minimum treatment requirements. Corresponding to decreasing levels of pollutant loading, DO available in the river to support aquatic life increased substantially (USEPA 2000).

2. Since the completion of secondary sewage treatment facilities at most major cities in the late 1970s, few low oxygen events occur unless wastewater treatment facilities are temporarily shut down for repairs, maintenance or emergencies (Pearson and Krumholz 1984). By 1987, Wellner and Dinger actually found elevated DO concentrations up to a mile downstream from major wastewater treatment plants, indicating the general effectiveness of wastewater treatment reaeration on DO.

3. ORSANCO's current minimum DO standard for the protection of aquatic life is an average of at least 5.0 mg/L for each calendar day with the minimum concentration not less than 4.0 mg/L. During the April 15 - June 15 fish spawning season, a minimum concentration of 5.0 mg/L is to be maintained at all times (ORSANCO 2003). These ORSANCO DO standards are consistent with standards of the states along the Ohio River. A classic study of DO concentrations and aquatic life conducted in the Ohio River established the notion that 5 mg/L DO was the boundary condition between little fish life and a reasonably productive community of mixed warmwater fish species (Brinley 1944 as cited in US EPA 1986).

4. Under the Clean Water Act (CWA), antidegradation guidance (USEPA 1983) has already been applied to management of minimum DO concentrations along the Ohio River. In applying this antidegradation policy guidance to hydropower development in the Ohio River basin, a minimum DO criterion of 6.5 mg/L was established as a lower boundary for no significant adverse impacts to warmwater fisheries. At present, there are no hydropower facilities operational on the Ohio River upstream of Hannibal Dam.

5.2.1.2.2 pH/Acidity/Alkalinity

1. During the 1960s and 1970s, much progress was achieved in reducing AMD pollution in the upper Ohio River Basin. The success of these efforts can be seen in the annual reports of ORSANCO for the period 1974-1980. In most of these years 100% compliance with established standards for pH was achieved at all monitoring stations in the

Ohio River (Pearson and Krumholz 1984). ORSANCO's current pH standard to protect aquatic life is between 6.0 and 9.0 standard units (ORSANCO 2003).

2. While it would appear that AMD problems in the Ohio River have been under control for the past several decades, much of the progress in the abatement of AMD has been achieved by mandatory treatment of the effluents of active coal mines. Treatment of these mine discharges was supposed to continue in perpetuity. However numerous mining operation bankruptcies have recently occurred, and will probably continue to occur in the future. Huge underground mining complexes have been abandoned, and are now flooding. Without intervention, these abandoned mines will eventually again discharge AMD to the waters of the upper Ohio River Basin. As of the time of this document preparation, no plan of action has been developed to deal with the potential problem.

5.2.1.2.3 Fecal Coliform Bacteria

1. With ORSANCO's requirement that all municipal wastewater treatment facilities provide secondary treatment, coliform bacteria levels in the Ohio River were expected to decline. This decline did not occur throughout the entire river, although decreases did occur in the upper 100 miles. In 1976, ORSANCO adopted the new federal drinking water standard of 2000 fecal coliforms/100mL, a standard that has remained to date. By 1978-79, ORSANCO reported nearly 100 percent compliance in the lower two-thirds of the river and compliance about 75 percent of the time in the upper 100 miles, where problems had previously been most acute (Pearson and Krumholz 1984).

2. After reviewing bacterial data through the 1980s, Pearson (1992) noted that the largest decreases in coliform bacteria in the Ohio River mainstem apparently occurred after primary sewage treatment facilities became operational, with the most dramatic declines reported in the upper 100 miles. Nevertheless, throughout the 1980s, most violations of the drinking water standard occurred in the upper river. The primary contact recreation standard of <200/100 mL, established for full-body exposure recreation (e.g. swimming and water skiing), also was violated frequently (Pearson 1992).

3. More recently, primary water born entric human diseases of concern include giardiasis and cryptosporidiosis. Also, amoebic meningoencephalitis from thermophilic *Naegleria fowleri* is a unique potential health problem in the thermal discharges, receiving waters, and cooling towers of the numerous power plants along the Ohio River (Sykora et al 1983).

5.2.1.2.4 Turbidity and Total Suspended Solids

Current agricultural practices, reforestation and runoff controls from construction sites help minimize sediment losses and reduce turbidity and TSS in water. ORSANCO's 2000 Pollution Control Standards include no specific turbidity or TSS standard for protection of aquatic life, but generally state that discharges to receiving waters be free from materials that will settle to form objectionable sludge deposits or suspended materials that will be unsightly or deleterious. Sewage must be treated so as not to exceed the TSS arithmetic mean in monthly samples of 30 mg/L or a weekly arithmetic mean of 45 mg/L. Although control programs have achieved some success in reducing turbidity and TSS, increased nutrient loads and runoff from impervious surfaces as a result of continued

development causes increases in algal productivity and pollutants attached to soil particles in water.

5.2.1.2.5 Nutrients

1. An ORSANCO study of long-term water quality trends from 1977 through 1987 indicated a strongly decreasing trend in ammonia nitrogen and a decreasing trend in total nitrogen, primarily related to wastewater treatment plant improvements and stringent discharge permit requirements (ORSANCO 1990). A strongly decreasing trend in total phosphorus observed basinwide during ORSANCO's 1977-1987 study was attributed to the switch to phosphate-free detergents.

2. Recent phosphorus data were collected between November 1996 and September 1999. No samples exceeded 1.0 mg/L from Hannibal L/D (RM 126.4) upstream and only a few samples exceeded that level downstream to Markland L/D. Numerous recordings above 1.0 mg/L occurred downstream from Markland L/D, primarily during the first half of 1997 (ORSANCO 2000a). These higher levels may have been related to increased runoff of agricultural chemicals.

3. Concerns about the effects of algal blooms on aquatic life and drinking water quality have led U.S. EPA to direct states to adopt water quality criteria for nutrients by 2004. Of specific concern are depressed oxygen levels in the Northern Gulf of Mexico (a condition known as Gulf Hypoxia), attributed to heavy nutrient loads in the Mississippi River. As a major tributary to the Mississippi, the Ohio River is a contributor to this problem. Algal blooms have not harmed aquatic life in the Ohio River, but drinking water suppliers have reported increased algal activity, which may result in taste and odor problems. Data from ongoing algal and nutrient analyses of Ohio River water supplies should assist in the development of appropriate nutrient criteria (ORSANCO 2001).

5.2.1.2.6 Sediments

1. Youger and Mitsch (1987) conducted a sediment study at 11 sites on the Ohio River, primarily upstream of navigation locks between Pittsburgh and Louisville. Concentrations of heavy metals generally decreased with distance downstream, paralleling a trend found in 1977 by ORSANCO. Lower concentrations of most metals, including cadmium, chromium, copper, iron, lead, nickel and zinc, were associated with a dramatic decrease in the iron and steel industry in the upper river from 1977 to 1987. With the exception of cadmium and zinc, a slight upturn in concentrations of all metals usually occurred at RM 531 immediately upstream from Markland Dam, illustrating the effects of past and present discharges from the Cincinnati metropolitan region. Youger and Mitsch found concentrations generally were well above background and, therefore, may be a source of contamination in the river for years to come.

2. Results of a 1980 study showed a tendency for sediments to not release priority pollutants to the water column with vigorous mixing (USACE 1981). Rather, there was a tendency for eluted sediments to adsorb to priority pollutant metals and remove them from the water column. This was consistent with findings of a study by Brannon et al (1976), which stated "no relationship existed between trace metal concentrations in the standard elutriate and total metal concentration in the sediments. This held true even though some

sediments were apparently highly contaminated with some trace metals. This clearly suggests that sediments can be a stable sink or repository for some contaminants."

3. Other studies, however, have demonstrated that it is possible for some sediment contaminants to be remobilized under some hydrologic conditions. In one example, severe episodic shock loads of phenols were being experienced at the Wheeling, West Virginia water intake during the 1980s. Since the shock loads were mostly associated with rising water levels during winter high flow periods, resuspension of river sediments was suspected to be contributing to the problem. The results of a 1988-1989 study (USACE 1989) confirmed this to be the case. Nichols et al (1983) pointed out that fluid mud (an intermediate stage between mobile suspend material and mud) is chemically important because it is a reservoir for potential toxics and a medium for chemical transfer.

4. A biological indicator of sediment quality, burrowing mayflies spend most of their life in fine grained sediment deposits, which are those most likely to be contaminated. These organisms were absent from the upper Ohio River (the area most severely degraded by industrial contaminants) for many years. Their failure to recolonize the upper river in the 1970s, after water quality substantially improved and numerous fish species returned, suggests lingering adverse impacts from legacy sediment contamination. During the 1990s, however, small to moderate numbers of burrowing mayflies were observed in the upper five pools of the Ohio River. First in 2001, and then again in 2002, mass emergences of burrowing mayflies occurred as far upstream as Pittsburgh.

5.2.1.3 Attainment of Ohio River Designated Uses

1. Section 305(b) of the Federal Clean Water Act requires biennial water quality assessments of the degree to which surface waters are attaining their designated uses. The Ohio River has four designated uses: warm water aquatic life, public water supply, fish consumption, and contact recreation. Three classifications are used to describe use attainment:

- fully supporting (good water quality)
- partially supporting (fair water quality) and
- not supporting (poor water quality).

2. In 1996, ORSANCO further divided the partially supporting use classification into three categories to provide additional descriptions: substantially supporting, moderately supporting, and marginally supporting. However, after two water quality report cycles, use of these subcategories was discontinued.

3. Attainment status for each designated use is described in sections 5.2.1.3.1 through 5.2.1.3.4.

5.2.1.3.1 Warm Water Aquatic Life

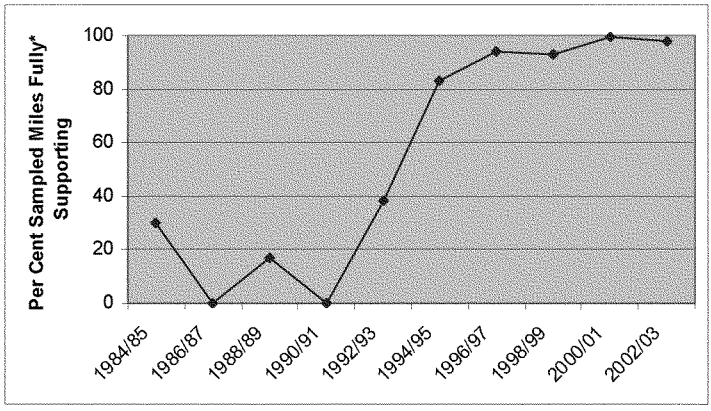
1. ORSANCO assesses Ohio River warm water aquatic life support based on chemical water quality data and measurements of fish communities using the recently developed Ohio River Fish Index (ORFIn). Dramatic increases in the number of Ohio River miles fully supporting warm water aquatic life have occurred since the mid-1980s as

Figure 5-1 illustrates. During the assessment for water years 2000-2001, 974 miles (99.3 percent) of the Ohio River were classified as fully supporting aquatic life.

2. Aquatic life use attainment in the Ohio River from 1984/85 through 1992/93 was probably higher than indicated in Figure 5-1. By the mid-1980's, biological assessments indicated that significant recoveries of fish and other aquatic life forms were occurring throughout the Ohio River. However, chemical assessments that routinely reported low level concentrations of total recoverable metals resulted in classification of these waters as "partially supporting" aquatic life use. Additionally, areas not attaining due to metals analysis did not appear to correlate well with areal distributions of recovering aquatic life forms.

3. Beginning in the 1994/95 monitoring period, several steps were initiated to develop assessment criteria that more accurately reflected aquatic life conditions in the river. The first step involved expanding the "partially supporting" category into 3 levels: substantially, moderately, and marginally supporting. A "weight of evidence" procedure was introduced to strike a balance between low-level findings of total recoverable metals and Modified Index of well being (MIwb) scores from fish population studies. For these monitoring periods, summation of the fully supporting and substantially supporting categories total 83% of sampled miles in 1994/95 and 94% in 1996/97.

FIGURE 5-1
Ohio River Aquatic Life Use Attainment



Note: represents "fully" plus "substantially" supporting for 1994/95 and 1996/97, represents "fully supporting" for all other years

4. Also during this time frame, ORSANCO initiated development of the ORFIn, expanding upon the MIwb to more accurately reflect fish communities and habitat conditions in the Ohio River.

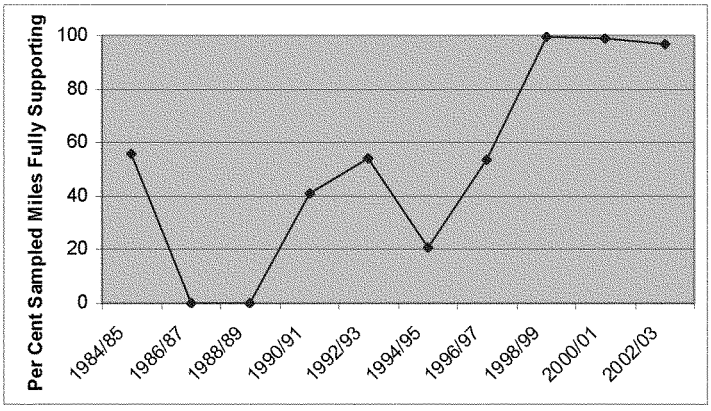
5. Beginning in the 1998/99 period, analysis for total recoverable metals was replaced with analysis for dissolved metals, which provided a better reflection of toxicity to aquatic life. This resulted in all of the "substantially supporting" miles being elevated to "fully supporting", for a total of 93% of sampled miles in this category. During the 1998/99 period, 61 miles remained in the "moderately supporting" category while 5.1 miles were downgraded to "marginally supporting", due to repeated fish kills from unknown point source contamination.

6. In the 2000/01 monitoring period, improved habitat conditions resulted in only 7 miles classified as "partially supporting". During this period, use of subcategories for "partially supporting" was discontinued. In the 2002/03 monitoring period, 'partially supporting" areas expanded to 16 river miles. This classification resulted from ORFIn scores that were below expected values (ORSANCO 2004b).

5.2.1.3.2 Public Water Supply

1. **Figure 5-2** illustrates that the number of Ohio River miles fully supporting public water supply use have also increased since the mid-1980s. Public water supply use is assessed based on chemical water quality data collected from ORSANCO's bimonthly sampling program, bacterial monitoring, and impacts on Ohio River drinking water utilities caused by source water conditions.

FIGURE 5-2
Ohio River Water Supply Use Attainment



2. Large and/or frequent industrial spills in the upper river and pesticide contamination from agricultural runoff in the lower river were the principle sources of public water supply impairment from the mid-1980's up to 1996/97. During the 1992/93 monitoring period, the upper 531 miles of river attained 'fully supporting" classification, while the lower 46% of the river attained "partially supporting" status due to pesticides (primarily atrazine) from agricultural runoff.

3. During 1994/95, a major spill of ethylene dibromide at river mile 203 contributed to a "partially supporting" classification for the entire downstream reach of the river. During 1996/97, detection of dioxin between river miles 237-317 and atrazine downstream from mile 607 resulted in a "partially supporting" rating on 46% of the river and "fully supporting" on the remaining 53%.

4. For the 1998/99 monitoring period, the assessment methodology for atrazine was changed from previous assessments. For this assessment, Ohio River atrazine levels were identified as a source of impairment when additional nonroutine treatment was required to meet the atrazine MCL (3.0 ug/L) in finished drinking water. The previous standard had been when atrazine concentrations in the Ohio River exceeded half of the finished drinking water MCL (1.5 ug/L). As a result, 997 miles were classified as "fully supporting". A segment of 4.4 miles in the lower river was classified as "partially supporting" due to point source contamination from1,2-dichloroethane.

5. Only relatively short stretches of the Ohio River have been classified as "partially supporting" for Public Water Supply in recent years. In both 2000/01 and 2002/03, approximately 10.5 miles from RM 161.7 though 172.2, were classified as partially supporting because the criterion for phenolics of 0.005 mg/L was exceeded in more than 10 percent of bimonthly samples at the Willow Island, WV, sampling station (ORSANCO 2004b, 2002). In 2002/03, an additional 22 miles of impairment were based on violations of bacterial stream criteria for the protection of public water supplies (ORSANCO 2004b).

5.2.1.3.3 Fish Consumption

During both the 2000-2001 and 1998-1999 assessments, all 981 miles of the Ohio River were classified as partially supporting fish consumption use (ORSANCO 2002, 2000c). Fish consumption use support is based primarily on the states' issuance of fish consumption advisories and ORSANCO fish contaminant data. The partially supporting designation is due to state advisory restrictions for PCBs; the majority of river miles were also partially supporting due to consumption restrictions related to mercury. Dioxin and chlordane have historically been fish tissue contaminants of concern. Chlordane has recently been removed from the list of substances impairing fish consumption; however, dioxin impaired 618 RM in 2000-2001 and 412 RM in 1998-99.

5.2.1.3.4 Contact Recreation

Contact recreation use support is assessed from data collected from May through October at ORSANCO's six recreation season monitoring stations on the mainstem downstream of urban centers with large combined sewer systems. Combined sewer overflows and other nonpoint sources, including animal waste handling practices, have been identified as significant causes of bacterial problems in the Ohio River, particularly during heavy rains. During the 2000-2001 contact recreation assessment, data from all monitoring stations indicated impaired contact recreation use. Approximately 40 miles (4 percent) of the Ohio River were classified as partially supporting contact recreation use and 136.5 miles (14 percent) were classified as not supporting. The remaining approximately 804 miles (82 percent) were not assessed. During the 1998-99 contact recreation assessment, 21 miles (2 percent) were classified as fully supporting contact recreation, 158 miles (16 percent) as partially supporting and 197 miles (20 percent) as not supporting. The remaining 605 miles (62 percent) were not assessed.

5.2.1.4 D evelopment of Total Maximum Daily Loads (TMDLs) for Various Pollutants in the River

1. Under USEPA regulations promulgated in 1992, states are required to identify water bodies that are not meeting water quality criteria established for specific designated uses (discussed above). For each impaired water body, a state must determine how much pollution reduction is needed to bring waters into attainment with their designated uses. The mechanism established to accomplish this is development of Total Maximum Daily Loads (TMDLs) for various pollutants. The TMDL program originated from Section 303(d) of the Clean Water Act. Present emphasis on TMDL program implementation has been driven by: 1) the realization that point source controls alone are insufficient to attain the nation's water quality goals and 2) citizen lawsuits forcing EPA to develop guidance for the TMDL program (CGER 2001).

2. Total Maximum Daily Load (TMDL) refers to the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Consequently, a TMDL represents the sum of allowable loads of a single pollutant from all contributing point, nonpoint, and natural sources. TMDLs currently are being developed for the Ohio River. In 1995, ORSANCO initiated its Ohio River Watershed Pollutant Reduction Program to investigate specific pollutants on a watershed basis. The resulting

pollutant-specific data have been valuable to TMDL development for dioxin and polychlorinated biphenyls (PCBs) in the Ohio River (ORSANCO 2001). Proposed TMDLs undergo technical review and public comment before being submitted to USEPA for final approval.

3. The dioxin TMDL was developed in 2000 and applies to the Ohio River from Racine L/D (RM 237.5) to the Big Sandy River (RM 317). Related data indicated that dioxin levels must be reduced from the Kanawha River and Upper Ohio in order to meet water quality standards. ORSANCO is conducting sampling of fish tissue, water sediments and air to further identify sources of dioxin. A TMDL for PCBs is to be completed for the West Virginia/Ohio portion of the river (RM 40 through RM 317) during 2002 (ORSANCO 2001).

5.2.2 Biological Resources

5.2.2.1 Fish

See Environmental Appendix, CEA Chapter 4 for an expanded discussion of fish of the Ohio River Mainstem

Fish of the Ohio River represent a highly visible and important environmental component; they have been studied more than any other biotic group in the river. The fish communities of the Ohio mainstem include a wide range of species, feeding levels and reproductive conditions that reflect varying degrees of environmental change. Factors important to sustaining viable fish populations include adequate water quality, habitat with stable substrates, adequate depth, suitable current and sufficient food supplies. Also important are reproductive viability and the capacity to tolerate disturbance caused by invasive species and river traffic.

5.2.2.1.1 Historical Conditions

1. A total of 159 species of fish have been reported for the Ohio River mainstem since the early 19th century. Reports prior to 1920 list 111 species; those from 1920-1969 list 121; and those from 1970-1988 list 140 species. Many human activities affected the river's environment before 1920, including clearing of forests and draining of wetlands leading to siltation, turbidity and habitat loss. After about 1900, species tolerant of siltation and turbidity increased in numbers, including black bullhead, goldeye, skipjack herring, gizzard shad and spotted bass. Before completion of the wicket dams in the early 20th century, large river species such as shovelnose sturgeon, paddlefish, muskellunge and blue sucker had declined. Rapid growth of human populations in the Ohio basin during the first half of the 20th century, led to larger inputs of domestic sewage, industrial effluents and acid mine drainage. Historic large river species continued to decline and gizzard shad, emerald shiner, freshwater drum and the introduced common carp became dominant. The fish communities of the more populous, industrialized upper river particularly declined.

2. The earlier wicket dams and the present system of high lift dams have altered aquatic habitats by converting the Ohio River from a free-flowing waterway to one of relatively constant width and a minimum maintained channel depth of 9 feet. The modern navigation system, combined with land use and flood control practices in the watershed, has resulted in the inundation and siltation of extensive areas of gravel bottom substrates,

which are preferred by important fish species, particularly in the lower half of the river. At the same time as reductions in migratory species related to high-lift dams have occurred, nearly 80 embayments in creek mouths adjacent to the mainstem have been created in the upper half of the river. Slow-moving waters of these embayments offer important habitat for basses and other sunfishes, which are fish more typical of lake-like conditions.

5.2.2.1.2 Current Trends

1. Actions by the Ohio River Valley Water Sanitation Commission (ORSANCO), an interstate Ohio River improvement organization founded in 1948, and the implementation of the Clean Water Act helped reverse declining trends such that an upward trend in fish diversity in the upper Ohio has been documented in the last 20 years. Many species that disappeared from the upper river during the worst decades of pollution have returned to portions of the river approximating their historical ranges. Between 1984 and 1989, range extensions of mainstem fishes included 12 species in an upstream direction, 14 species in a downstream direction and six species both upstream and downstream. Further, improved water quality improvements are reflected in an ORSANCO list of the most abundant species captured during river surveys. Pollution tolerant common carp and bullheads have been replaced by bluegill, temperate basses and other fishes less tolerant of pollution. ORSANCO has recently developed a tool, the Ohio River Fish Index (ORFIn) which incorporates distinctive ecological characteristics and 13 attributes of Ohio River fish communities to evaluate their ecological health.

2. In spite of continued research and measurable improvements related to fish communities, stability of Ohio River native fishes is now a concern related to introduction within the last decade of four species of Asian carps (grass, silver, bighead and black). These species have little sport value, but can aggressively compete with native fishes for food and space. The impacts of Asian carps on Ohio River native fishes are still undetermined. The American Fisheries Society published a book entitled "Black Carp: Biological Synopsis and Risk Assessment of an Introduced Fish" (Nico, et al, 2005) that should be useful in developing strategies to consider in the Ohio River system for black carp management.

5.2.2.1.3 Recent Studies

1. During the past and into the present, many studies have been conducted to determine the effects of various human activities on fishes of the Ohio River. Key observations from these studies follow:

- A recent study on upstream fish passage at Ohio River dams, undertaken to examine the importance of longitudinal connectivity between navigation pools in sustaining migratory fishes, suggested that upstream fish passage opportunities generally occur during open-river rather than controlled conditions at dams. Open river conditions occur when dam gates have been lifted clear of the water and are no longer controlling water levels behind dams. Therefore, at open river the surface water elevation immediately upstream and downstream from a dam are nearly equal. An analysis of historical water elevation data at Ohio River mainstem dams revealed that the frequency of open river by calendar week (hence, the potential for fish passage) varied spatially along the river by dam and temporally

with discharge. The general spatial pattern of open river indicated the potential for fish passage decreases from downstream to upstream. In general, open-river conditions were more frequent during winter and spring and generally were nonexistent during summer and fall, coinciding with the low-flow period. The study suggests that because large river fish populations evolved under conditions less restrictive to between-pool movement than presently exist, conditions created by mainstem dams probably affect the distribution, abundance and productivity of migratory species by imposing limitations on reproduction and genetic exchange among localized fish populations.

- Additional studies undertaken for ORMSS related to fish movement and passage in the Ohio River supported some findings of the upstream fish passage study above and are briefly summarized below:

    1) A fish passage direct observations study, conducted at Winfield L/D on the Kanawha River, showed that large river migratory fishes (e.g. white bass, skipjack herring, sauger) were more common in tailwater areas than in the lock chambers, while species typical of more lakelike conditions (e.g. channel catfish) were more common in the lock chambers. This finding supports ORSANCO observations that fewer large river species are collected in traditional lock chamber surveys than expected based on their overall abundance in the river. Further, results of the direct observation study led to the reasoning that many migratory species are not attracted to flow conditions in lock chambers and, therefore, miss opportunities to pass through lock/dam complexes during typical navigational lockage operation.

    2) A fish tagging and recovery study, conducted in nine tailwater areas along the Ohio River, supported the findings of the fish passage direct observations study and indicated that migratory fishes' attraction for flowing waters inhibits them from entering lock chambers. Instead, their interpool movement appears to be facilitated by more open river conditions, which occur more frequently at some L/Ds than at others.

    3) A recreational fish survey of more than 8,500 angler trips at eight tailwaters and covering all seasons found that the number of anglers fishing for "any species" exceeded the number targeting a single species or group and totaled 33 percent of anglers on the river overall. Geographic differences also were observed in species sought; for example, fishes in the perch family were sought in more upstream tailwaters while catfish were sought more frequently in downstream tailwaters. Consumption advisories may explain that fewer fish were kept by anglers in the more industrialized upper river than in the more rural lower river.

- Studies on the effects of towboat operation on large rivers indicate that propellers of commercial towboats can cause abrupt changes in hydraulic patterns, including increased turbulence and water velocities that cause injury or mortality of adult fish, eggs and larval stages. Field investigations of these effects have been limited, in part because of the difficulty of sampling organisms in turbulent water behind large vessels. Two recent studies prepared for the Corps on the Upper Mississippi

River-Illinois Waterway may be applicable to the Ohio mainstem. First, a study of larval shovelnose sturgeon, larval lake sturgeon, eggs and larvae of paddlefish, juvenile common carp, and larval blue sucker (all species recorded for the Ohio mainstem.) found that larval mortalities varied by size and species, with higher tolerances by larger individuals and by species adapted to higher velocity habitats. The study concluded that shear stress created by propellers can be a major source of larval fish mortality. A second study, in Pool 26 of the Upper Mississippi and Alton Pool in the Illinois River, concluded that high annual tow traffic can yield high estimates of annual losses.

- The ORMSS project did not undertake a study on the effects of recreational boating on fish and habitat, but a literature review by the North American Lake Management Society emphasizes that impacts of recreational boating on fish and other aquatic life are most pronounced in shallow waters and are compounded by the coinciding of peak boating activity with critical life stages of aquatic organisms during warmer months. Wave action by high-speed watercraft can disturb or destroy spawning nests, promote shoreline erosion, smother fish eggs and habitat, and lead to gill damage causing decreased growth rates and lower fish biomass overall. Most studies cited in the literature review focus on lakes and reservoirs and fish species that typically inhabit them. Because scant information exists on the effects of recreational boating on large rivers, it remains a topic ripe for additional research.

- A study of winter habitat used by fishes in the Ohio River, conducted during two recent winters in the Belleville and Smithland Pools, found that during both winters and in both pools, fish communities and abundances differed among habitats. For example, in Smithland Pool, habitats adjacent to the main channel appeared to be important for fish during the winter, including island backwaters, submerged boulders at the channel border, and deep scours created by artificial structures. Tributaries in Smithland Pool only appeared to provide important winter habitat when temperatures were low and when tributaries areas were connected to the main channel and not blocked by silt. In Belleville Pool, tributaries and an embayment area appeared to be important for wintering fishes, although such areas may cool more than the main channel during snow melt, stimulating fish to move into warmer main channel areas. The unique opportunity to conduct parallel research projects in two Ohio River pools during the same winters provided several insights into the potential effects of increased navigation fish: 1) Tributary habitats are clearly important to wintering fish; reduced connections between tributaries and Smithland Pool likely compromises the success of many species. 2) Artificial sites such as wing dikes in Smithland Pool create scours used by river fishes. 3) Island backwater areas appear particularly important for fishes during winter. In the Ohio mainstem, quantity and availability of winter refuge may well determine the relative survival and abundance of resident fish populations. Therefore, river habitat management that maintains or enhances accessibility to these areas should be beneficial to wintering fish in the Ohio River.

- Studies on the effects of cooling water intake structures on fish have been undertaken along the Ohio River since the 1970s in conformance with Section 316(b) of the Clean Water Act. In accordance with new and proposed regulations

related to §316(b), U.S. EPA recently evaluated entrainment and impingement rates at nine power plants on the Ohio mainstem between RM 53.9 and 560. The main fish species the study found to be at risk were emerald shiner, freshwater drum, gizzard shad, sauger, white bass, white crappie, and white sucker. Several of these species have floating eggs or larvae that make them more vulnerable to damage from water intakes. Further §316(b) studies at several power plants along the Ohio River are anticipated as additional phases of the revised 316(b) program are implemented by U.S. EPA in the coming years.

2. Finally, a tool to evaluate river traffic impacts on habitat for fish and other aquatic life current has been developed by the USACE – Louisville District to evaluate aquatic life. Called the Navigation Predictive Analysis Technique (NAVPAT), the tool is a habitat model that links tow movements to possible biological effects by considering 15 life-stages of fishes typical of various fish groups and habitats in the Ohio River system. Although refinements to NAVPAT continue, the model has been used to evaluate environmental effects near Olmsted L/D and McAlpine L/D.

5.2.2.2 Mussels

See Environmental Appendix, CEA Chapter 5 for an expanded discussion of Ohio River mussels

Because of limited mobility, mussels are subject to a variety of environmental factors that can restrict their distribution and reproductive success. Payne and Miller (1999) found that long-term stability of Ohio River mussel beds depends on clay, silt and sand, which are deposited during seasonal low flows, being removed by high flows without eroding underlying gravel and cobble. Other factors important to sustaining viable mussel communities include adequate water quality; availability and distribution of fish hosts for colonization by young mussels (glochidia); and restricting the introductions and abundance of non-native, invasive species.

5.2.2.2.1 Historical Conditions

1. As long ago as the late 1800s, freshwater mussels had begun to decline in the Ohio River, primarily from direct habitat disturbances, as well as indirect effects of siltation, pollution and contaminants associated with construction, industry and agriculture (Taylor 1989). In the 19th Century, harvesting of freshwater mussels for button manufacture began in the Ohio River. Harvesting mussels for the button industry continued through the mid-20th century until the advent of plastic buttons, which are cheaper and more easily manufactured. Mussel harvesting along the river, however, continued beyond the 1950s in response to the cultured pearl industry's demand for small mussel pellets to stimulate pearl growth. As late as the 1980s, 22 active commercial mussel harvesters were operating on the Ohio and Tennessee Rivers (Williams and Schuster 1989).

2. Construction of dams on the Ohio River further affected native mussels. First they impounded water and inundated mussel habitats. Second, the dams formed barriers that separated and isolated the populations of mussels. These barriers also affected the distribution of fish species that serve as hosts to the larval phase (glochidia) of the mussel. This affected the ability of certain mussel species to recolonize areas of suitable habitat.

Third, changes in current velocity and direction associated with high-lift dams have had impacts on mussel beds. High-lift dams are the newer generation dams constructed by the Corps. High lift dams created deeper pools than the first generation of "low-lift" dams. As current velocity diminishes upstream of dams, deposition of silt seems to particularly affect younger mussels. Younger mussels are small enough to sink into the silt and suffocate. When lower lift dams were in place, in many areas the current followed the shoreline washing mussel beds free of silt and mud. With the completion of high-lift dams, current patterns changed, allowing greater deposition of silt (Williams and Schuster 1989).

5.2.2.2.1.1 Mussels in the Upper Mainstem River

1. This section describes historical factors affecting freshwater mussels and conditions of the mussel community from Pittsburgh (RM 0) to Meldahl Lock and Dam (RM 436). Mussels were completely extirpated from the upper portion of the Ohio River during the early 20th Century. Arnold Ortmann (1919), in his classic monograph of the *Naiades* of Pennsylvania, reported the total demise of the mussel fauna of many tributaries of the upper Ohio River, mostly from the impacts of acid drainage from bituminous coal mining. However, in 1919 he was still able to document either the presence, or relatively recent occurrence, of a diverse assemblage of at least 39 species of mussels in the Pennsylvania portion of the mainstem of the Ohio River.

2. The degree, extent, and duration to which previous water quality conditions adversely affected survival of mussels along the upper Ohio River cannot be precisely determined from historical data. However, as early as 1914, the U.S. Public Health Service documented episodic acidification of the Ohio River extending as far as 170 miles downstream of Pittsburgh (U.S. Public Health Service 1924). Data collected by the U.S. Geological Survey and the Pennsylvania Department of Forests and Waters (White 1951) provide a good picture of Ohio River water quality conditions (at a station 17 miles downstream of Pittsburgh) during the late 1940s. The pH of the Ohio River ranged from 3.65 to 6.6 and averaged 5.3 (pH of 7.0 is neutral). Other water quality factors affecting mussels in the upper river included low DO, high turbidity and suspended solids, and high concentrations of contaminants (e.g., metals and organic compounds).

5.2.2.2.1.2 Mussels in Other Mainstem Reaches

Mussel communities from Mehldahl Lock and Dam (RM 436) to the confluence of the Ohio and Mississippi Rivers (RM 981) were less affected by historical water quality conditions than were mussels of the upper Ohio River. This is due in large part to the upper river reach being more heavily industrialized than the rest of the river. Although mussels were definitely affected by water quality factors from upstream sources, major influences along the middle and lower reaches were from low DO, high turbidity and suspended solids, and contamination of sediments.

5.2.2.2.2 Recent Conditions and Trends

1. With the enactment of the Federal Water Pollution Control Act Amendments in 1972, water quality conditions began to improve on the mainstem Ohio River and throughout the Nation. As water quality improved, mussel resources began to also

improve. However, by this time, many of the modern, high lift locks and dams on the mainstem Ohio River were in place. Presence of these dams restricts fish movement among pools and has slowed reestablishment of freshwater mussel populations. Another major factor setting back mussel recovery was introduction of the non-native zebra mussel in the Ohio River around 1990. Zebra mussels negatively affect native mussels primarily by smothering siphons, preventing valve opening and closure, and interfering with normal feeding and burrowing. Further, living freshwater mussels are a preferred substrate for zebra mussels (Ricciardi et al. 1995).

2. Several federally listed threatened or endangered species of freshwater mussels that were once found in the Ohio River are considered to be extirpated from the mainstem, including the white wartyback, cracking pearlymussel, rough pigtoe, winged mapleleaf, northern riffleshell and catspaw. The ring pink may be present but no live specimens have been collected in recent years. The tuberculed-blossom pearlymussel may be extinct. Although historical records indicate the dromedary pearlymussel once occurred in the Ohio River, definitive data are not available (USFWS 2000). Five federally listed endangered native mussel species, however, are currently known to exist in the Ohio River mainstem. These are the fanshell, pink mucket, orangefoot pimpleback, clubshell, and fat pocketbook.

3. Two additional historic Ohio River mussels are listed by the USFWS as candidate species – the sheepnose mussel (*Plethobasus cyphus*) found as recently as 1994 in the Newburgh and Markland pools and the spectaclecase (*Cumberlandia monodonta*) which may be extirpated from the Ohio River. Candidate species are organisms for which the USFWS has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act (http://endangered.fws.gov/candidates/).

5.2.2.2.2.1 Mussels in the Upper Mainstem River

1. Studies conducted since 1991 indicate that some species of mussels are recolonizing the upper to middle Ohio River mainstem, reflecting in large part the revitalization the river has undergone in recent years due to more stringent water quality standards (ESI 2000, Cavanaugh and Mitsch 1989). As recently as 1980, Taylor found only sub fossil shells and no living mussels in the Pennsylvania reach of the Ohio River. However, the OSU compilation of mussel records revealed two records of mussel occurrence (1979 and 1984) in the Montgomery pool. It appears that recolonization of Emsworth, Dashields, and Montgomery Pools by mussels is a very recent phenomenon.

2. ESI 2000 concluded that the present fauna of the upper Ohio River appears to be a mix of historical species and new species that have recently colonized the study area from tributaries and downstream pools. Researchers have recently found evidence of 54 species, including 35 species that historically appeared in this portion of the river and 19 new species that have recently become established in the upper river. This considerably expands the number of species reported for the upper Ohio River by Taylor (1989). Of the 54 species for which evidence was found (including weathered and sub fossil shells), one species is presumed extinct, eight species are considered extirpated from the study area and the status of two species is unknown. Ten species thought extirpated from the upper river, however, were found live or as freshly dead shells. Indications of recent recruitment were observed for 15 species, including five species previously thought extirpated. There are no

recent records of live specimens of any federally listed threatened or endangered species in the Ohio River mainstem upstream from the Willow Island Dam, although Watters (2003) suggests the fanshell probably occurs in Dashields pool.

Patterns in the ESI data suggest that recolonization is occurring primarily from downstream as evidenced by:

- decreasing species richness and abundance in more upstream pools, and
- opportunistic habitat use in upstream pools.

3. Mussel beds (defined as areas where mussels are consistently found in greater abundance than in surrounding areas and where several species and young animals are present) occur as far upstream as Willow Island Pool (ESI 2000). However, recruitment in recent years was only apparent in a few areas in Willow Island Pool and density was low (<5 mussels /m^2). Density was still low to moderate (<10 mussels /m^2) between Belleville and Meldahl Pools, but species richness increased and recruitment was good in many areas sampled.

4. Increasing trends of total mussel species and rare mussel species (those species comprising <1% of the total collected) from upstream to downstream pools in the upper river further illustrate the recolonization pattern of Ohio River mussel fauna.

5.2.2.2.2.2 Mussels in Other Mainstem Reaches

1. Williams and Schuster (1989), whose studies somewhat geographically overlap the ESI database, reported a net loss of 18.6 linear miles of mussel beds between RM 317 and RM 981 since 1967. The most drastic change was the complete absence of mussel beds in 51.8 miles of the Ohio River above McAlpine L/D. In the interval between 1967 and 1982, within the study area, four new high-lift dams (Cannelton, Newburgh, John T. Myers and Smithland) replaced wicket dams. Other high-lift dams completed during the 1960s had been operational for nearly 20 years.

2. The non-indigenous Asiatic clam (*Corbicula fluminea*) appears to have no adverse effects on native mussels in the Ohio River. Since 1993, Asiatic clam populations have greatly declined; however, zebra mussels (first appearing in the Ohio River in 1991) have replaced Asiatic clams as the non-indigenous bivalve of primary concern. Zebra mussel density near Olmsted L/D was 49,000 individuals per square meter in 1994, but was reduced to 5,000 per square meter in 1995. High zebra mussel densities in 1994 resulted in reduced growth of native mussels, but did not cause major declines in density of native mussels such as have occurred in the Great Lakes. It remains to be seen if zebra mussels can sustain sufficiently high abundance in the lower Ohio to have drastic effects on native mussels.

3. Intensive mussel surveys have been conducted since 1983 in the lower Ohio River near Olmsted, Illinois, to assess the ecological effects of construction and operation of a new lock and dam at RM 964.4 that will replace existing Locks and Dams 52 and 53. Upon completion, the new Olmsted Dam will increase water levels by a maximum of 10 ft. in the pool above the dam during periods of normal and low flow (approximately 42 percent of the year). A mussel bed is located upstream of Olmsted Dam near the Post

Creek outlet at RM 956.5 (Payne and Miller 2002). In addition to changes in the upstream pool area, navigation traffic patterns and river currents immediately downstream of the new dam will be altered. These projected changes are of special interest with respect to their possible impacts on a dense, diverse mussel bed that occurs from approximately RM 966.7 to 969. Mussel studies near Olmsted Lock and Dam are anticipated to continue until the project has been in operation for several years.

5.2.2.3 Other Aquatic Life

See Environmental Appendix, CEA Chapter 3 for an expanded discussion of Ohio River phytoplankton and macroinvertebrates

All aquatic organisms, from minute microscopic plankton to the largest fish, reflect the water quality of their environment and, thus, potentially can serve as biological indicators of water quality conditions and trends. Smaller organisms, especially algae and macroinvertebrates, have most often been studied in this regard, in part, because of their relative ease in field collection and laboratory processing. Bioassessments in general may be used within a planning and management framework to prioritize water quality problems for more stringent assessments and to document "environmental recovery" following control action. Characterization of water quality has been the primary motivation for the biological surveys which have been conducted along the river by ORSANCO since 1957.

5.2.2.3.1 Phytoplankton of the Ohio River Mainstem

Algae form a basis of the food chain and are a foundational component of the Ohio River ecosystem. Algae in running waters may occur as attached forms on all types of solid objects including macrophytes and as films on mud and silt surfaces. Algae also occur as free floating or planktonic forms. Ohio River researchers have confirmed that phytoplankton communities are very important in the Ohio River. Monitoring has to a large degree been motivated by a history of water supply taste and odor problems and public health concerns. In recent years these concerns have expanded to include control of cryptosporidious disease by filtration of the oocysts of the protozoan *Cryptosporidium parvum* during algae blooms (USACE 1994).

5.2.2.3.1.1 Ohio River Plankton Studies - 1957 to 1960

Between October 1957 and January 1960, Jackson and W eise (ORSANCO 1962) collected 210 plankton samples al ong the Ohio River. Over th e length of the river, they concluded that diatoms generally dominated the phytoplankton community. While species composition was sim ilar along the length of the river, there were quan titative longitudinal variations, with generally depressed concen trations of phytoplankton in the polluted upper portion of the river. T hey suggested that ac id mine drainage pollu tion contributed by the Monongahela River depressed phytoplankton a bundance in the upper river. A number of algae bloom events were docum ented at various locations between river m iles 307 and 642, typically involving diatoms and blue-green algae.

5.2.2.3.1.2 Ohio River Plankton Studies - 1974 to 1975

The U.S. Army Corps of Engineers (1975) sampled phytoplankton along the upper Ohio River between RM 1.0 and 129.2 in 1974. Similar to the findings of Jackson and

Weise (1962), they observed that the microflora of the Ohio River was dominated by diatoms and green algae,. Blue-green algae were conspicuously absent from the upper Ohio River, even during late summer. Since blue-green algae are very sensitive to acid conditions, it was speculated that the influence of acid mine drainage may have limited blue-green algae growth in the upper river at that time. Phytoplankton concentrations in near surface samples were generally elevated in the lower sections of navigation pools where velocities are low, and were reduced downstream of navigation dams where velocities and turbulence increase as water passes the dam.

5.2.2.3.1.3 Ohio River Plankton Studies during the 1990s

1. No published plankton data from the 1980s are available. However, during the 1990s, Wehr and Thorp (1997) conducted a study of the effects of navigation dams, tributaries and littoral zones on phytoplankton communities in a reach of the Ohio River that extended roughly from Cincinnati to Evansville. Their study demonstrated that the Ohio River supports diverse, substantial phytoplankton communities, with densities comparable to other large rivers in North America. They observed 134 algal and cyanobacteria taxa, with about 60% of the species diversity contributed by diatoms. As with previous and subsequent investigations, cyanobacteria and green algae attained their greatest prominence in the summer while diatoms were most prominent during the cooler months.

2. Wehr and Thorp concluded that Ohio River phytoplankton densities increased with temperature and decreased with current velocity. Tributaries to the study reach of the river appeared to have few effects on either phytoplankton or zooplankton, probably because of the considerably higher flow of the Ohio River relative to its tributaries in this reach. Consequently, the plankton community of the Ohio River would appear to consist of "true" resident populations.

5.2.2.3.1.4 Distribution and Abundance of Phytoplankton along the Ohio River in 2002

1. In July 1999, the Ohio River Valley Water Sanitation Commission (ORSANCO), in cooperation with the University of Cincinnati, Northern Kentucky University and ten major public water supply utilities, initiated an ambitious program to monitor phytoplankton and chlorophyll along the Ohio River. Organisms are identified and enumerated at the genus level from samples collected twice per month, year round, at each of the ten water supply intakes. The most recent complete year with available organized sampling data is 2002. Data from that year showed a tendency for concentrations of both chlorophyll and phytoplankton to increase in a downstream direction in the Ohio River.

2. The percentage of phytoplankton organisms capable of producing taste and odor problems and the percentage of organisms which were blue-green algae were less in the upper river than in the middle or lower portions of the river. Conversely, the percentage of diatoms was highest in the upper river. The percentage of organisms generally considered to be tolerant of pollution was lowest in the lower river. Factors which might contribute to these spatial trends are the increasing size and lower relief of the river as it flows along its 981 mile long course, the longer navigation pools towards lower portions of the river, and warmer water temperatures in the more southerly lower reaches of the river. Seasonal

patterns apparent in the ORSANCO data show that phytoplankton is least abundant during the higher flow and colder winter months and most abundant during the lower flow and velocity warmer summer months.

3. The composition of the Ohio River phytoplankton community is complex, containing over a hundred genera. However, some generalizations can clearly be made:

- Overwhelmingly, the phytoplankton community of the river was dominated by diatoms.
- The green algae *Chlamydomonas* and *Chlorella,* and *Cryptomonas* were also occasional dominants.
- Despite the concerns related to blue-green algae blooms, blue-green algae were only dominant in 2.8% of the Ohio River samples collected in 2002.

4. The recent ORSANCO length of river, year round sampling study initiative is by far the most ambitious and comprehensive attempt to monitor and characterize the phytoplankton community of the Ohio River. From the data available to date, the results of this effort appear to be generally consistent with Hynes' (1970) characterizations of large temperate zone rivers, as well as the results of previous Ohio River phytoplankton investigations. An apparent decline in pollution tolerant and potential taste and odor causing phytoplankton organisms suggests possible improving water quality and ecological health along most of the Ohio River. Continued monitoring will allow for verification of potential trends.

5.2.2.3.2 Aquatic Macroinvertebrates of the Ohio River Mainstem

1. In addition to their intrinsic values and importance as food for fish and other forms of aquatic life and often non-aquatic life, benthic macroinvertebrate communities are also highly responsive indices of water quality. Macroinvertebrate quality evaluations are based on the principle that invertebrate communities of non-degraded streams are composed of many different types of organisms, including pollution intolerant taxa such as mayflies, stoneflies, and caddisflies (Ephemeroptera, Plecoptera, and Trichoptera, or EPT organisms). The invertebrate communities of polluted streams, on the other hand, are dominated by a small number of pollution tolerant taxa such as sludge worms and bloodworms (Annelida and Chironomidae, or AC organisms). Between the extremes are numerous organisms with intermediate tolerances.

2. The following discussion of Ohio River macroinvertebrates excludes freshwater unionid mussels, which are discussed in **Section 5.2.2.2.**

5.2.2.3.2.1 Ohio River Macroinvertebrate Studies - 1957 to 1960

1. Between October 1957 and January 1960, ORSANCO (Jackson and Weise 1962) collected invertebrate samples along the length of the Ohio River. They found that invertebrate communities of rocky substrates along the main channel of the Ohio River did not include any species which are indicative of unpolluted water. The invertebrate communities of soft substrates nearer to shore were even more depauperate, consisting only of very pollution tolerant tubificid worms and a few specimens of the bloodworm chironomid *Tendipes* sp.

2. More intensive sampling near the intake of the Louisville Water Company at RM 600 confirmed that the distribution of benthic organisms in the Ohio River was related to its substrate type. Similarly, Thorp (1992) demonstrated that invertebrate taxonomic richness and density in the Ohio River is significantly influenced by substrate composition, and also references numerous supporting studies from other locations. Samples of different types of bottoms and from various depths revealed fewer organisms on bottoms of sand or sand and silt than on bottoms of silt alone.

3. Jackson and Weise also emphasized that only a few specimens of Ephemeroptera (mayflies) were found in the Ohio River during their 1957 to 1960 study period. Ephemeroptera are generally considered to be indices of good water quality. Due to water quality improvements over the more than four decades since completion of the Jackson and Weise survey, burrowing mayflies have gradually returned to the entire Ohio River. Huge, newsworthy, emergences of burrowing mayflies finally returned to the Pittsburgh reach of the Ohio River only in 2002/2003.

5.2.2.3.2.2 Ohio River Macroinvertebrate Studies - 1963 to 1967

The results of an intensive Ohio River cooperative aquatic macroinvertebrate monitoring effort, conducted between 1963 and 1967, were published by U.S. Environmental Protection Agency in 1971 (Mason et al.). This effort used artificial substrate sampling (rock baskets) to eliminate the variable of bottom substrate. Important conclusions developed by Mason et al were that artificial substrate sampling techniques tended to collect more diverse samples than dredge samples and that during the five year study period the abundance and diversity of macroinvertebrates increased at stations along the lower and middle reaches of the Ohio River, but not yet in the upper reach of the river near Pittsburgh. Throughout 1963-67, dredge samples from the upper part of the river contained only pollution-tolerant sludgeworms and a few bloodworms.

5.2.2.3.2.3 Invertebrate Community Condition Scores - Patterns and Trends

Invertebrate community condition score and metrics for 2002 ORSANCO data were plotted against 1967 condition scores. The results clearly demonstrate that dramatic improvements have occurred along the previous severely impaired upper reach of the Ohio River since 1967, but less so or not at all along the moderately to slightly impaired middle part of the river. Notwithstanding the progress to date, results for the upper and middle river, compared to the higher condition scores for the lower river, suggest that there is still considerable room for improvement along the upper and middle reaches of the Ohio River.

5.2.2.3.2.4 Invertebrate Signature Species

The extensive ORSANCO Ohio River aquatic macroinvertebrate data file is a valuable large river ecosystem information resource with the potential to yield numerous important insights into the ecology not only of the Ohio River, but also perhaps of other large temperate regulated rivers. While the examination of the file should be considered cursory, some characteristics of the fauna are evident. Among these is the presence of certain organisms, which because of their ubiquitous distribution and/or abundance might be considered to be Ohio River invertebrate signature species. One candidate example is

the almost uniquely large river habitat caddisfly *Cyrnellus fratermus*, present in 88% of the rock basket samples examined. and comprising fully 58.1% of the total number of all invertebrate organisms collected from the Ohio River in 1967, and 39.4% of all 2002 organisms. Identification of important system specific taxa, such as the crustacean *Gammerus minus* and the mayfly *Baetis flavistriga* in urban drainage in the upper Ohio River Valley (Koryak et al 2003), can also be used to help refine rating metrics.

5.2.2.3.2.5 Influence of Navigation Dams on Invertebrate Communities

Characteristics of invertebrate rock basket communities from samples collected by ORSANCO upstream and downstream of Ohio River navigation dams in 2002 show that taxa richness and mean condition scores were somewhat higher downstream of the dams. However, other parameters demonstrated slightly more negative values downstream of the dams and the data is probably inconclusive. If there are more diverse and healthier invertebrate macroinvertebrate communities in the tailwaters of the dams than within their pools, the composition of these communities is probably correlated with natural substrate. The artificial substrate sampling techniques used would not reflect such natural variations in the substrate of the river.

5.2.2.3.2.6 Influence of Islands on Benthic Macroinvertebrate Communities

Thorp (1992) demonstrated linkages between islands and benthos in the Ohio River, with implications for riverine management and aquatic ecosystem restoration opportunities. He found islands to have significant positive effects on invertebrate density and diversity that appeared to be related to changes in physical habitat characteristics. He also noted that islands interrupt the deepwater regions of the Ohio River ecosystem by providing shallow-water habitats and access to different forms of food. Jahn and Anderson (1986) also found that the macroinvertebrate fauna in large rivers shows significant spatial variation among different habitats within the same pool. Thorp specifically recommends island preservation and construction to foster aquatic habitat heterogeneity, and notes that island construction has been employed in several large rivers, such as the Mississippi, with consistently satisfactory results.

5.3 LAND USE

See Environmental Appendix, CEA Exhibit D for an expanded discussion of land use patterns along the Ohio River mainstem corridor

5.3.1 Historical Conditions

Land use changes occur as a result of population increases or decreases in localized areas. Economic development and infrastructure projects can also lead to direct changes in land use as well as associated changes in population density. River-related land use applies these concepts to address how human use of the Ohio River has shaped or influenced associated land use patterns and what land use changes may be anticipated in the foreseeable future.

5.3.1.1 Pre – 1920

1. Pioneer settlement within the Ohio River valley prior to the 1790's was constrained by French and British interests in maintaining their claims of sovereignty within the region. Following the American Revolution, colonization of the area was accomplished by awarding lands in the Northwest Territories to veterans of the war. However, Native American resistance (often supported by British influences) continued to minimize colonial settlements in the area. It was not until Anthony Wayne's victory at the Battle of Fallen Timbers in northwestern Ohio in 1794 and the conclusion of the Treaty of Greeneville in 1795 that the threat of Indian attacks on Upper Ohio River settlements was eliminated and the development of towns and communities in the river valley could proceed unimpeded (ACE_c pg. 3-8). The population within the Ohio Valley grew from 125,000 in 1790 (the first Federal Census) to 850,000 in 1810 (ACE_c 3-55).

2. The decades of pre-settlement military activity necessitated establishment of fortifications along the Ohio River or its tributaries and these often became the sites of the earliest settlements within the region. The most notable example is Pittsburgh, located at Fort Pitt (circa 1758), other examples include fortifications preceding the establishment of towns at Marietta, OH and Wheeling and Point Pleasant, WV (ACE_c 3-8). Other factors contributing to the initial location of towns along the Ohio River generally included the availability of high ground for a town site above the flood zone, connectivity between the town and a productive hinterland, and certain 'port development opportunities' such as the Falls of the Ohio at Louisville or location of the national road crossing at Wheeling. Initial settlements within the region tended to cluster along the Ohio River because the river was the primary access to the region.

3. A variety of factors influenced the subsequent growth and decline of Ohio River towns from 1830's to 1920's. Some early riverfront settlements subsequently prospered as hubs or service centers to interior regions accessed through these towns. As the hinterlands developed, the river towns continued to grow as ports for the assembly and shipping of the region's produce. During the early decades of this period, the Ohio River provided the primary mode of transportation, both for immigration of new settlers and for transport of regional products. The earliest flatboats and keelboats mostly provided one-way transport downstream, necessitating shipment of produce through New Orleans and coastal shipping to reach eastern markets. The arrival of steamboats around 1815 permitted two-way traffic and greatly reduced travel times (ACE_c 3-60). However, the Ohio River itself remained largely unimproved prior to the 1920's, and the ability to move produce was constrained by the seasonal availability of high water flows sufficient to support navigation. Development of the Ohio River in the 1800's included the removal of snags, completion of the initial canal and locks around the Falls of the Ohio at Louisville in 1833, and completion of the first wicket dam (Davis Island, Pittsburgh) in 1885.

4. The latter part of this era includes the period of heavy industrial development along the middle and upper Ohio River. This development centered on the iron and steel industry in Pittsburgh, with its convergence of proximity to raw materials, coal, river water, and rail and river transportation to move materials and produce into and out of this center. An almost continuous band of industrial development became established along the Ohio River floodplain from Weirton to Pittsburgh. To compensate for the limited availability of high ground within this corridor, industries built up elevation of the

floodplain for their developments. The steel industry typically used large quantities of slag as fill material (Rieger, personal communication).

5.3.1.2 Settlement and Development Patterns 1920 to Present

1. Construction of the system of wicket locks and dams ultimately revitalized the Ohio River as a major transportation corridor. Following construction of the first project in 1885 (Davis Island) the next lock and dam was not finished until 1904. Six lock and dam projects were completed between 1904 and 1910, 23 were completed between 1911 and 1920, and the entire system of 50 lock and dam projects was completed by 1929. The original design for a navigation depth of six feet was modified in 1910 to provide for a nine-foot depth.

2. Even as construction of the slackwater system continued, river traffic declined. In 1917, cargo carried on the river reached a low of about 4.6 million tons, a nadir caused largely by the abrupt halt of coal shipments from Pittsburgh to New Orleans. The turning point for the slackwater system was during World War I. Wartime shipping overburdened the country's land transportation system and by 1920, cargo volume on the Ohio River had risen to almost 9.4 million tons, a total that increased further to 10.8 million tons in 1924 (Froggett 1926a), 16 million tons by 1925 (Froggett 1926b), and 22.3 million tons by 1930 (Robinson 1983:28-29; USACE-ORD 1979:22). Where traffic once consisted primarily of coal and steel products moving downstream, new products were being added as the century progressed. Freight soon included petroleum and its products, iron and steel, dry and liquid chemicals, grain, cement, and a variety of other items (Gaum 1970:487), and upstream traffic substantially increased in volume.

3. Commerce on the river grew steadily through the 1930s and 1940s while development of diesel towboats and larger barges created opportunities for larger scale, more efficient movement of commodities. Designed for about 15 million tons of commerce annually, the old locks and dams handled more than 70 million tons in 1954; in addition, traffic moving upstream on the Ohio had nearly equaled that moving downstream. Plans to improve system efficiency and accommodate the larger tugs and barges called for reducing the number of dams by building high-lift projects with larger capacity locks. The final plan, approved in 1954, envisioned a total of 19 high-lift projects with dual lock chambers and began with the construction of Greenup and New Cumberland L&Ds, although construction of Emsworth, Dashields, Montgomery and Gallipolis L&Ds during the 1930s had already replaced some old locks and wicket dams on the upper river. Olmsted, which will complete the 1954 modernization plan, is currently under construction and will replace L&D 52 and 53 (Johnson, 1992).

4. During this era of sustained urban growth, the demands of industrial and commercial development outpaced the availability of land within some of the rapidly growing riverfront urban centers. Within the Huntington and Louisville Districts, a series of levee and floodwall projects were completed during the 1930s and 1940s to protect existing properties against flooding. Rapidly growing cities also expanded beyond the river floodplain to higher ground, utilizing mass transit (light rail, bus) and automobiles to connect their expanding fringe with the urban riverfront core.

5. The availability of reliable, inexpensive electric power contributed significantly to the industrial and commercial growth of the Ohio Valley. Construction of the wicket dams contributed to bulk transport of the region's coal and provided stable pool elevations. Over the years, availability of abundant supplies of cooling water and economies of river transport of coal have favored development of the very large power plants that are now a part of the riverfront landscape of the Ohio Valley.

5.3.2 Present Descriptions

5.3.2.1 Pittsburgh, PA to Steubenville, OH; river mile 0 to 62 (Pittsburgh, PA)

1. The floodplain is very constricted, with the river at ordinary high water typically accounting for 30 to 60 per cent of total area of the floodplain (defined as approximately level terrain between steeper bluffs). Low and high-density urban uses (commercial, industrial, high-density residential and low-density residential) dominate all the floodplain, including islands in the upper half of the river reach. Deciduous forest dominates bluffs or steep areas adjacent to the river outside urbanized areas, whereas low-density residential or deciduous forest dominates bluffs within the urbanized areas. Eight islands are presently located in this stretch of river (*see Environmental Appendix, CEA Chapter 6, Table 6-10).*

2. Low and high-density urban uses dominate upland areas in the eastern half of the area (Pittsburgh area) and also in Beaver, PA, and East Liverpool, OH. Deciduous forest and pasture are the principal land uses outside of the urbanized areas. Only a few small areas of cropland or mixed forest (mixed deciduous and evergreen forest) are visible.

5.3.2.2 Steubenville, OH to Parkersburg, WV; river mile 62 to 187

1. The floodplain is very constricted. Significant low and high-density urban uses occur along the full length of this reach and are the dominant land use within the floodplain upstream of Moundsville, WV. The floodplain is primarily in row crops or pasture outside of the urbanized areas, with only a few small areas of deciduous forest. Deciduous or mixed forest dominates bluffs or steep areas adjacent to the river. Twenty-three islands are located in this reach.

2. Deciduous forest dominates land use in the upland areas, with pasture as the secondary use. A few urban patches are scattered through upland areas upstream of Moundsville but are confined to upland areas adjacent to the river in communities downstream to Parkersburg. Patches of mixed forest occur throughout the uplands. Only a few small areas of row crop use are visible, some mining or transitional surface use is also visible.

5.3.2.3 Parkersburg, WV to Ironton, OH; river mile 187 to 323

1. The floodplain is very constricted, widening somewhat in the Huntington to Ironton area. The reach between Huntington and Parkersburg is primarily rural, with only a few small urban areas visible at Gallipolis/Point Pleasant, WV, Cheshire, OH, and Pomeroy, WV. Land use in the floodplain in this section is a mixture of pasture and row crop. Urban land uses dominate the floodplain between Huntington and Ironton. Seven islands remain within this segment of the Ohio River.

2. Deciduous forests dominate Upland areas, with pasture the secondary land use. Patches of mixed forest and areas of mining or transitional surface use occur throughout the uplands along with a few small areas of row crops.

5.3.2.4 Ironton, OH to Foster, KY; river mile 323 to 439

1. The floodplain remains wider from the Ironton/Huntington area to west of Portsmouth, OH, then gradually returns to the constricted configuration of the upper river. Land use within the floodplain is primarily row crops with some pasture and a few small areas of wooded wetlands. Vegetation on the bluff areas adjacent to the river is primarily deciduous. Urban land use within the floodplain is found at Ironton/Greenup, Portsmouth, and Maysville. Three islands are located along this segment of the river.

2. Upland areas are predominately deciduous forest in the eastern and central portions of this area, but give way to mixed pasture and row crops in the western third. Significant row crops are also evident in the broad floodplain of the Scioto River above Portsmouth and significant wooded wetlands occur in floodplains of the Little Sandy River southeast of Portsmouth. Areas of mining or transitional use are scattered through the eastern portion of this area.

5.3.2.5 Foster, KY to Ghent, KY; river mile 439 to 537

1. The floodplain remains constricted through the eastern portion of this reach, with the river surface typically accounting for 40 to 60 per cent of the floodplain area. Downstream of the confluence with the Great Miami River, the floodplain broadens somewhat, with the river surface typically accounting for 20 to 40 per cent of the floodplain area. Low and high-density urban use dominates the floodplain in the Cincinnati/Covington/Newport area. Urban use is also visible west of Cincinnati at Cleves, Oh and Lawrenceburg and Rising Sun, IN. Land use in the floodplain east of Cincinnati is primarily a mix of row crops and pasture. Row crops dominate land use in the broader floodplain west of Cincinnati, with some pasture and a few small areas of wooded wetlands. Only one island remains in this reach.

2. Urban uses dominate upland areas adjacent to the Cincinnati area and also occur in scattered patches north, east and south of Cincinnati. Non-urban areas throughout the region include a mix of row crop, pasture, and deciduous forest, with significant row crop areas in the Great Miami floodplain and several areas of wooded wetlands in the floodplains of tributary streams in Kentucky.

5.3.2.6 Ghent, KY to West Point, KY; river mile 537 to 630

1. The floodplain returns to the more constricted form, with river surface accounting for 40 to 60 per cent of the floodplain area. Low and high-density urban use dominates the floodplain in the Louisville/Clarksville/Jeffersonville area. Urban use is also visible east of Louisville at Madison, In, Carrolton, KY, and Vevay/Ghent. Floodplain use outside of urban areas includes a mix of row crops, pasture, and some wooded wetlands. Deciduous forest dominates bluff areas adjacent to the river. Six islands occur within in this reach.

2. Urban uses dominate upland areas surrounding Louisville and are also visible as smaller patches throughout the area. Non-urban areas throughout the region include a mix of row crop, pasture, and deciduous forest use, with significant areas of wooded wetlands in tributary floodplains northeast of Louisville and scattered patches of mixed forest in Indiana. The Indiana Army Ammunition Plant is a large commercial/industrial area north of Louisville.

5.3.2.7 West Point, KY to Lewisport, KY; river mile 630 to 737

1. The floodplain gradually widens from east to west through this reach of the river, with river surface accounting for 20 to 40 per cent of floodplain area in the western area. Urban land use within the floodplain is restricted to a few small centers, including Tell City, IN and Brandenburg, KY. Row crops and pasture are the dominant land uses within the floodplain, with a few small areas of wooded wetlands. Deciduous forest is prominent along bluffs adjacent to the river. There are four islands in this reach.

2. Upland areas include deciduous forest (dominant in the central area) and mixed row crop and pasture (dominant in the east and west portions of the area). Significant urban use is located in the Fort Knox area and significant wooded wetlands are located in bottomlands of the Salt River on the east side of Fort Knox.

5.3.2.8 Lewisport, KY to Wabash River, IN; river mile 737 to 848

1. The floodplain continues to widen from east to west through this reach of the river, with river surface accounting for 10 to 20 per cent of floodplain area near the Wabash River confluence. Limited urban land use occurs in floodplain areas of Evansville, IN and Henderson and Owensboro, KY but the majority of urban area for these cities is located on adjacent uplands. Extensive areas of row crop agriculture dominate floodplain land use, with significant secondary areas of wooded wetlands and some pasture and deciduous forest. Deciduous forest is also prominent along bluffs adjacent to the river. This reach includes seventeen islands.

2. Row crop agriculture and pasture (including significant row crop agriculture in the Wabash River floodplain) dominate land use in upland areas, with lesser tracts of deciduous forest and some significant areas of wooded wetlands along tributary floodplains. Several areas of mining activity, scattered tracts of mixed forest, and a few urban centers (Morganfield and Sebree, KY) are also visible.

5.3.2.9 Wabash River, IN to Cairo, IL; river miles 848 to 981

1. The floodplain is narrowed somewhat near Shawnee National Forest southwest of the Wabash River but returns to a broad floodplain configuration from Paducah to the confluence with the Mississippi River. Limited urban land use occurs in floodplain areas of Paducah, KY, and Metropolis and Cairo, IL. Row crop agriculture is the dominant floodplain land use, with significant secondary areas of wooded wetlands and some pasture and deciduous forest. Deciduous forest is also prominent along bluffs adjacent to the river. Twenty-four islands are found here.

2. Upland land use includes a mix of row crop agriculture, pasture and deciduous forest, with significant areas of wooded wetlands in tributary bottomlands and some fairly large blocks of mixed forest. Significant urban land use is visible in areas adjacent to Paducah and at Calvert City, KY.

5.3.3 Trends

1. With respect to statewide trends, all six states along the Ohio River mainstem are showing significant increases in the amount of developed land. Additionally, the rate of development has increased in all six states. Cumulatively for the six states, 0.6 percent of total land area was developed from 1982 to 1987, 0.8 percent was developed from 1987 to 1992, and 1.2 percent from 1992 to 1997 (double the 1982-1987 development rate). The total area of developed land within the six states increased by 32 percent during the 15 years covered by these data. This compares closely to the national increase of 34 percent during the same period. Nationally, an average of 1.4 million acres per year was developed from 1982 to 1992. This increased to an average of 2.2 million/year from 1992 to 1997.

2. It seems likely that the accelerating rate of development illustrated above continued from 1997 to 2002 (the latest year for which data were considered). Housing construction did not slow, partly because of federal interest rate reductions that contributed to record low mortgage rates. A conservative estimate would set land developed from 1997 to 2002 as equal to the total developed from 1992 through 1997, or 1.2 percent of total land within the six states. Thus it is estimated that 11.7 percent of total land area within the six states was developed for urban/commercial/industrial use as of 2002.

5.4 RIPARIAN/FLOODPLAIN ECOLOGY

See Environmental Appendix, CEA Chapter 6 for an expanded discussion of Riparian/Floodplain Ecology for the Ohio River Mainstem

1. Riparian/floodplain resources include terrestrial habitats, wetlands, soils and geology, islands, and floodplain hydrology. The following definition for "riparian", which was developed by the National Research Council (2002), encompasses the above components and related processes:

2. Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients of biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral stream, lakes, and estuarine-marine shorelines (NRC 2002).

3. Further, riparian areas include portions of the channeled system and associated features (gravel bars, islands, wood debris); a vegetated zone of varying successional states influenced by floods, sediment deposition, soil-formation processes and water availability; and a transitional zone to the uplands of the valley wall – all underlain by alluvial aquifers. Although they occupy only a small portion of the total land base in most watersheds,

riparian areas are regional hot spots for biodiversity and exhibit high rates of biological productivity in contrast to larger landscapes (NRC 2002).

4. Each of the identified components and related processes are influenced by both natural processes and man-induced stresses. For example, compounding the influence of natural processes are changed floodplain hydrology and characteristics resulting from development projects or other human induced changes in land use. These influences include dams and other instream developments, activities along the riverbank or within the riparian zone, and upstream activities throughout the watershed. The floodplain hydrology resulting from the combination of natural and human influences, subsequently, affects the full spectrum of riparian features. It also significantly affects the suitability of the riparian zone for various human activities such as agriculture, recreation, transportation, housing and commerce.

5. For purposes of describing the affected environment, the following components, processes, habitats and species are addressed: physiography and geomorphic considerations, floodplain descriptions, soils and sedimentation, hydrological considerations, corridors, riparian habitats, wetlands, bottomland hardwood forests, riparian edge/shoreline areas, embayments, islands, upland and unique habitats, wildlife, and invasive exotic species.

5.4.1 Historical Conditions

1. Based on average annual discharge, the Ohio River is the second largest river in the United States, surpassed only by the Mississippi River, below its confluence with the Ohio (USGS streamflow data, cited in USEPA 2000). The Ohio River is formed by the confluence of the Allegheny and Monongahela rivers in Pittsburgh, Pennsylvania, and flows 981 miles in a southwesterly direction to join the Mississippi River at Cairo, Illinois. The elevation of the Ohio's riverbed drops 429 feet from the headwaters to its confluence with the Mississippi River (USEPA 2000). The mainstem's major tributaries, from upstream to downstream, include the Muskingum, Kanawha, Guyandotte, Big Sandy, Scioto, Licking, Great Miami, Kentucky, Green, Wabash, Cumberland, and Tennessee rivers. The 203,940 sq.-mi. Ohio River basin encompasses several physiographic provinces, but the Ohio mainstem is primarily influenced by four provinces: Appalachian plateau (RM 0 to RM 380), central lowlands (north of the Ohio River from central Ohio through Indiana and Illinois), interior low plateau (RM 380 to RM 928), and coastal plain (RM 928 to RM 981). Due to the broad scale of these physiographic and geomorphic considerations, the historical and recent conditions are essentially the same, thus no trends are noted.

2. The dimensions of the Ohio River floodplain in various river reaches are influenced by the erodibility of the rocks forming the valley. The floodplain is narrow upstream (e.g. 0.8 mi. at Pittsburgh) as it flows through a relatively flat-laying sequence of sedimentary rocks. By Vanceburg, KY (RM 380) the floodplain has broadened to 1.6 miles, but then remains fairly narrow almost to Louisville, because the valley walls are formed by relatively resistant shaly limestone. From above Louisville to West Point, KY (RM 630), the floodplain widens where more erodible soft shales form the valley walls. Downstream from West Point, however, the river enters an area of more resistant limestone and the valley narrows for approximately 90 miles. Near Hawesville, KY (RM

724), the valley enters soft shale and sandstone and, consequently, broadens. The valley narrows again near Shawneetown, IL (RM 858) where more resistant sandstones occur, then broadens near the confluence with the Cumberland River (RM 920), where the floodplain consists of soft unconsolidated sediments of the Mississippi Valley (USACE 2000). Due to the broad scale of the floodplain along the mainstem, the historical and current conditions are essentially the same. However, localized changes in the floodplain have occurred along the mainstem as a result of both local and upstream land use changes, as well as a consequence of river flow pattern changes from upstream dams and locks operations.

3. Riparian soils are highly variable in structure, particle size distribution, and other factors that occur not only horizontally across a riparian area but also vertically within a soil profile. Such variability results from interactions between streamflow patterns and sediment transport in conjunction with variations in local geology, channel morphology, and streamside vegetation. Sediments deposited on floodplains undergo biogeochemical changes that occur over time to transform flood-deposited sediment into riparian soils which, because of their high levels of nutrient and organic matter, are some of the most productive agricultural soils in the nation. The alluvial sediments along the upper River valley consist of glaciofluvial fill or medium to coarse-grained sand and gravel of Wisconsin Stage and post-glacial terrace deposits mainly of the "point-bar" type of river sediment. These glaciofluvial deposits are as much as 125 feet thick. The downstream floodplains commonly consist of thick sections of sand, silt, and clay that are commonly referred to as loams.

4. Regarding hydrological considerations, riparian areas receive water from direct precipitation, groundwater discharge, overland and shallow subsurface flow, from adjacent uplands, and from the Ohio River by various pathways. It is estimated that 4,500 billion gallons of water is stored in the mainstem's alluvial aquifer, with more than 70% being in the lower third of the River. Due to the shallow depth of this aquifer, this aquifer is also sensitive to pollution. The quality of the groundwater is characterized by relatively high hardness and dissolved solids concentrations.

5.4.2 Recent Conditions and Trends

1. Many ecological functions along the Ohio River have been lost, as riparian areas have become hydrologically disconnected from their adjacent stream channels. Such disconnections occur, for example, when local topography and soils are altered by agricultural activities or by development and its associated infrastructure. Floodplain and instream sand and gravel mining also potentially modify riparian hydrology, influencing groundwater levels, overbank flow, bank stability and the character of riparian vegetation. Impoundment of the river for navigation has elevated the water table and has significantly affected Riparian/Floodplain Resources. Deepwater habitats of navigation pools have replaced the varied habitats of islands, gravel bars, riffles, and channel wetlands, while some new habitats have been created in embayments.

2. The USWFS (2000) analyzed aerial photos to estimate the miles of riparian habitat remaining along the Ohio River. The analysis used 1800 as a benchmark year and assumed that at that time, the entire river corridor was forested, therefore, encompassing 1,962 linear miles on both banks of the river. The length of the remaining intact riparian

forested areas along each riverbank was calculated by examining aerial photographs from randomly selected 20-mile stretches of river in the Pittsburgh, Huntington and Louisville Corps districts. Intact riparian forested areas were defined as having stable, undeveloped banks that support mature native riparian vegetation of sufficient width to provide some habitat value and/or provide buffering from mainland development. The percent forested riparian areas for each evaluated reach was calculated and extrapolated to determine the total number of riparian habitat miles remaining. The analysis indicates that slightly more than 50% of all types of riparian habitat along the Ohio River have been lost since 1800. Additionally, disproportionate losses in the upper and middle river are consistent with historic patterns of settlement and development.

3. Bottomland hardwood forests are temporarily or seasonally flooded areas that usually occur along streams and rivers, usually in mineral soils. They represent the natural climax community of the Ohio River floodplain. Industrial, residential and agricultural development, draining, and construction of dams and navigation pools have eliminated much of this habitat type. In fact, between 1800 and 1970, approximately 1,235,000 acres (65%) of the Ohio mainstem's forested floodplain habitat was lost or converted to other uses (Ohio River Basin Commission 1978). Prior to development, a typical floodplain habitat was a matrix of bottomland forest interspersed with components of other wetland types, including sloughs and oxbows. The remaining riparian area is often less than a few hundred feet wide (USFWS 2000).

4. Riparian edge/shoreline areas are physical, chemical and biological transition zones between terrestrial habitats and open water. Such areas are important for a variety of birds, mammals, amphibians, reptiles and fishes, dependent on this limited habitat type. Rooted aquatic plants or macrophytes, however, represent a conspicuous group of organisms primarily found in riparian edge/shoreline areas, as well as in embayments. Nine species of submerged plants have been observed along the Ohio River and backwaters, including eelgrass and water nymphs. Further, a total of 24 species of emergent plants have been noted, including water willow, lizardtail and duck potato.

5. Most remaining shallow water and wetland habitats in the Ohio mainstem floodplain occur in the embayments – the tributary mouths inundated by backwaters from the impounded Ohio River (USFWS 2000). Major wetland habitat types in embayments include riverine open water, riverine emergent, riverine aquatic bed, palustrine open water, palustrine emergent, palustrine scrub/shrub, and palustrine forested.

6. In summer, during the height of the growing season, the diversity of the wetland plants and habitat types in Ohio River embayments provide excellent food and cover for migratory and resident wildlife. The shallow water habitats are important feeding areas for wading birds such as great blue herons, great egrets and black-crowned night herons, which nest in heronries nearby and feed in the embayments while raising their young. After fledging, juvenile herons concentrate in the embayments as well. Wood ducks, mallards, and Canada geese nest and raise their broods in the embayments and along the mainland wetlands in summer.

7. The most comprehensive assessment of embayments and wetlands along the Ohio River has occurred in the Ohio River Islands National Wildlife Refuge's planning area, which encompasses approximately 400 Ohio River miles from the Montgomery to

Mehldahl pools. More than 5,400 acres of relatively undisturbed embayments and mainland wetlands are affected by Ohio River backwaters and have some significance for wildlife.

8. Recently, the Ohio River Islands National Wildlife Refuge (ORINWR) office completed a comprehensive assessment of the number and acreages of islands lost from the Ohio River since 1900. Of 124 islands present according to 1911-1914 navigation charts, 31 islands have disappeared, including 20 from the upper river. While some islands in the lower river have increased in size since 1900, the overall acreage gain of 1,094.8 is far outweighed by the 12,001.3 acres lost. The ORINWR analysis indicates an overall loss of 43.1 percent of historic island acreage, due primarily to pool raises, construction of high-lift dams on islands and dredging (USFWS, undated).

9. Historically, the Ohio River floodplain was primarily forested habitat, with scattered prairies, canebrakes and wetlands in the floodplains of the main river and its tributaries. Scattered remnant unique habitats such as dry forest glades, post oak flatwoods and clay barrens may still be found. Bluffs bordering some areas of the Ohio River shoreline provide habitat for a number of species of concern. Most of this area has been settled, cleared, drained, farmed and developed, resulting in the outright loss of habitat, and the fragmentation of that which remains. Significant wildlife use of upland forests in the study area includes the endangered Indiana bat and gray bat, raptors (including nesting bald eagles) and neotropical migrant songbirds.

10. The varied riparian habitats along the Ohio River support a diverse assemblage of wildlife. Birds are an especially important component of wildlife along the river and are conspicuous by their numbers, visibility and overall species diversity. Riparian areas' diversity in plant species and variations in vertical and horizontal structure provide an array of niches for birds. Riparian areas along the Ohio River mainstem afford important habitat for breeding birds, stopover habitat for migratory birds and wintering habitat for birds that live in North America year-round. The Ohio River corridor is poised on the boundary between the Atlantic and Pacific Flyways, and is a major migration route for birds.

11. Over 25 species of waterfowl (ducks, geese, swans, mergansers) utilize the Ohio River corridor. The majority of these species are migratory, using riparian habitats as feeding and nesting areas. Numerous shorebirds (e.g. lesser and greater yellowlegs, spotted sandpipers, semipalmated plovers, ruddy turnstone, common snipe, American woodcock, solitary sandpiper, least sandpiper, semipalmated sandpiper and killdeer) utilize the Ohio River corridor during spring and fall migration. Important areas include mudflats and emergent wetlands. The USFWS (2000) notes that before the Ohio River was extensively altered, its floodplains and tributaries provided numerous sandbars, mudflats and oxbows that were ideal habitat for shorebirds.

12. The great blue heron and green-backed herons are the most commonly observed wading birds along the Ohio River. Both species feed and roost in shallow water zones, fringe wetlands and interior wetlands along the river and islands. Wading birds also include the interior least tern, listed as federally endangered due to low numbers and loss and degradation of nesting islands. The bald eagle, formerly an threatened species under the Endangered Species Act, also occurs in the Ohio River corridor although in 2007 it was

delisted. This species is still protected under the Bald and Golden Eagle Protection Act, the Migratory Bird Treaty Act and the Lacey Act. The USFWS (2000) indicates bald eagles are more abundant along the Ohio River in winter than at other times of the year, as they shift south from frozen lakes and rivers in the north.

13. More than 25 mammal species occur along the Ohio River mainstem, including furbearers such as mink, beaver and muskrat. These species are noticeably more abundant along back channels and wetland habitats of embayments than along the main channel/navigation sides of islands (USFWS 2000). Somewhat less conspicuous are the endangered Indiana bat and gray bat that roost along the river during summer. Although not as conspicuous as birds or mammals, most amphibians and many reptiles are intimately associated with riparian areas and their waterbodies. Many species of amphibians and reptiles are found in Ohio River riparian zones, although most have not been well studied. However, the 15 species of reptiles and amphibians documented as of 2000 for the Ohio River Islands National Wildlife Refuge (USFWS 2000) might be considered to be representative of the typical herpetofauna common to the Ohio River riparian zone.

14. The only Federally endangered, threatened, proposed or candidate species of reptile or amphibian listed in the USFWS's Ohio River Valley Ecosystem Team website for counties contiguous with the Ohio River mainstem is the copperbelly water snake (*Nerodia erythrogaster neglecta*), found in several counties in Southern Illinois. In Indiana and Ohio the copperbelly water snake is threatened in the northern part of its range, but is not listed in these states in the southern part of its range near the Ohio River. However, Conservation Agreements have been signed between USFWS and the Illinois, Indiana, and Kentucky Departments of Natural Resources, other state agencies, and a number of coal companies as a means of protecting and enhancing habitat for the copperbelly water snake in the southern portion of its range.

15. Invasive exotic plant species have become an extremely serious problem along the Ohio River floodplain. In fact, the USFWS considers invasive exotic plants second only to direct habitat losses as a threat to native species (USFWS 2000, and Morrison 2003). Along the RM 0 to 437 river reach considered within the scope of the Ohio River Islands National Wildlife Refuge's management strategy, one of the greatest obstacles to efforts to restore and protect wildlife habitat is invasion by non-native plants such as Japanese knotweed, mile-a-minute, and multiflora rose. The riparian corridor along this reach of the Ohio River includes a diverse assemblage of about 500 species of plants. Of these, 39 species are considered rare, 100 species are considered exotic, and 35 species are problematic invasive exotic species.

5.5 AIR QUALITY

See Environmental Appendix, CEA Chapter 7 for an expanded discussion of Air Quality within the Ohio River corridor

Air pollutant emissions are broadly classified as originating from two types of sources, stationary and mobile. Stationary sources generally include facilities such as industrial plants and electrical power generating plants, whereas mobile sources include automobiles, trucks, trains, boats, and any other equipment that is not at a fixed location.

5.5.1 Historical Conditions

1. Extensive and diverse industrial development in the ORV began in the 1800s and, up to about 1970, occurred without substantive regulation of air emissions. In addition, rapid highway development occurred from 1945 through 1970, which contributed to the growing popularity of the automobile as well as development of an extensive commercial trucking industry. As was the case with industrial sources, emissions from automobiles and trucks were unregulated up through at least 1970.

2. Gasoline and diesel fuel from mobile sources added lead, Volatile Organic Compounds (VOC), Carbon Monoxide (CO), Nitrous Oxides (NOx), Particulate Matter (PM) and other pollutants to the air. USEPA estimates that national emissions of NOx increased 690 percent between 1900 and 1970. During the same period, VOC emissions increased 260 percent and Sulfur Dioxide (SO_2) increased by 210 percent. Air quality trends in the ORV probably approximate these national trends with the exception of SO_2, which was very heavily concentrated in the ORV due to the amount of coal burned in the region.

3. Many local air pollution problems are the result of population centers and local weather patterns that concentrate pollutants over a period of several days. The most obvious localized impacts of smog, PM, and lead attracted much public attention during the two decades of debate that preceded passage of the Clean Air Act and finalization of Federal air quality regulations in the early 1970's. Long-range transport and atmospheric chemical interactions that contributed to acid rain, formation of Ozone (O_3), and other impacts were less obvious. However, the earliest legislation established monitoring and research programs that led to better understanding of these processes.

4. One of the earliest programs to improve air quality focused on the automobile. Beginning in the mid-1970's, all new vehicles sold in the U.S. were required to have catalytic converters, which reduced emissions and enabled the vehicles to operate on unleaded gasoline. Additional engine design and performance standards also contributed to reduced emissions of VOC and CO. Subsequent fuel efficiency standards reduced emissions by increasing the number of miles traveled per gallon of fuel consumed. Significant progress towards improved air quality was gradually achieved over about 15 years as the previous generation of leaded vehicles was gradually replaced.

5.5.2 Recent Conditions and Trends

1. In general, regional conditions in the ORV reflect the national pattern for overall improvement in air quality. Between 1970 and 1999, total emissions of the six National Ambient Air Quality Standards (NAAQS) pollutants have decreased by 31 percent. These advances were achieved in concert with significant economic and population growth. During the same time period, U.S. Gross Domestic Product increased 147 percent, vehicle miles traveled increased 140 percent, and the U.S. population increased by 33 percent. Since 1970, emissions from all of the NAAQS pollutants have decreased, with the exception of NOx. Between 1970 and 1999, emissions of NOx increased 17 percent. The majority of this increase is due to heavy-duty diesel vehicles and coal-fired power plants.

2. VOCs combine with NOx to form O_3. Substantial progress has been made in the control of this class of pollutants; however, future gains will be more difficult to achieve. For this region, sulfates are the primary precursor to the formation of $PM_{2.5}$, accounting for over 50 percent of particulate composition at monitoring stations east of the Mississippi River. NOx is an important secondary precursor. The acid rain program, regional NOx programs, and NOx vehicle initiatives are the primary activities that will contribute to reduced $PM_{2.5}$ emissions in the ORV. In addition to the national acid rain program, three regional programs are in effect that will further reduce NOx emissions from power plants and other industrial sources in the Midwest and northeast. In this region, NOx shares principal contributor status with VOC for local ozone problems, with SO_2 for acid rain, and is a secondary contributor to the formation of $PM_{2.5}$.

3. Overall compliance with air quality standards is indicated by whether an area is designated to be in attainment with requirements for various pollutants. Achievement of attainment status for O_3 in the seven county Cincinnati and Northern Kentucky area and for SO_2 in Gallia County reflects the trend towards attainment status for numerous localities in the ORV. However, revised standards for O_3 and $PM_{2.5}$ seem likely to place numerous localities into nonattainment status for one or both of these NAAQS. Some localities will have to continue or reinstate air quality programs from earlier periods of noncompliance status (e.g. Cincinnati and Northern Kentucky), while others will be required to implement programs for the first time. Programs for both pollutants would primarily focus on transportation management, public education, and emergency procedures. In some cases, nonattainment localities may acquire the authority to impose stricter emission limits for NOx, SO_2, VOC, and $PM_{2.5}$ from stationary sources such as printers, distilleries, dry cleaners, industrial boilers, and related sources.

4. For areas that are nonattainment for O_3 in the ORV, as well as for communities trying to maintain their attainment status, transportation management is one of the primary strategies at the local level. Vehicle inspection programs are a fundamental means of assuring that owners perform routine maintenance to keep their vehicle emissions in compliance. Communities can also require the use of reformulated fuels that burn more efficiently and emit fewer pollutants. Support of mass transit programs is motivated, in part, to reduce vehicle emissions.

5. Local program efforts are supplanted with emergency procedure approaches when local air quality threatens to exceed compliance thresholds. Local authorities may encourage or require reduced activities by public agencies, local industries, area sources, and individuals until air quality improves.

5.6 HUMAN HEALTH AND SAFETY

See Environmental Appendix, CEA Chapter 8 for an expanded discussion of Health and Safety within the Ohio River corridor

Health and safety (H&S) considerations are primarily related to human communities rather than resources and ecosystems. However, some H&S measures may impact resources or ecosystems. The H&S VEC consists of:

- Worker health and safety – This refers to construction workers and workers related to lock and dam operation, assemblage/ disassemblage of barges in tow, operation of tows and helper boats, and barge loading/unloading.

- General population health – This refers to chemical or bacteriological exposures to the human population using the Ohio River as a water supply, or using the river for body contact recreation (swimming and/or water skiing) or consuming fish from the River.

- Recreational boater safety – This refers to accidents experienced by those persons engaged in recreational boating on the Ohio River.

- Noise refers to the ambient sounds audible in an area or environment, comprised of sounds from varying distances. Both workers and the general population may be subject to noise impacts.

5.6.1 Historic Conditions

5.6.1.1 Hazardous Industries, Waste Sites and Spills

Industrial activities located or conducted in proximity to the river have posed one or more types of public risk. These included pollution point sources, production and disposal of hazardous wastes, and spills of potentially hazardous or polluting materials associated with transfer, storage and use of the materials. Past industrial activities also contributed to the creation of contaminated sites and landfills that pose ongoing threats to groundwater, surface water or public health. Raw materials, products, and wastes associated with river oriented industrial activity were transported locally and regionally by barge, rail, and truck. These materials were subject to spillage while in transit and especially at material transfer points.

5.6.1.2 Recreational Boating

Recreational boating on the Ohio River was subject to higher levels of risk than normally encountered on inland lakes and streams. Strong currents, water level fluctuations and the presence of barge traffic were more prevalent on the Ohio River than in other settings. Recreational boating on the Ohio River resulted in a number of injuries, fatalities, and associated property damage. Boating and other river oriented recreational activities grew significantly over the past several decades in conjunction with improving water quality (see Env. App. CEA Chapter 9, Recreation).

5.6.1.3 Water Quality

Poor water quality limited recreational activities prior to recent improvements brought about by the Clean Water Act and associated enforcement starting in the 1970s. Industrial contamination adversely affected fish populations and led to imposition of fish consumption advisories all along the river. Temporary impacts following wet weather worsened conditions by increasing fecal coliform counts in urban areas. Major spills of oil or chemicals threatened drinking water supplies.

5.6.1.4 Noise Impacts

Noise impacts have historically been associated with general industrial activities such as mining activities, coal utilities, and other river-oriented industries that produced significant, ongoing or frequent noise impacts. Additional noise sources may include construction activity at large project sites such as lock extensions, dam rehabilitation, various other Corps activities, and major construction activity conducted by others. In all cases, the potential importance of noise impacts is a function of the population, including sensitive groups, living in close proximity to the source of the noise.

5.6.2 Recent Conditions and Trends

5.6.2.1 Hazardous Industries, Waste Sites and Spills

1. Certain industrial activities, waste sites, and spill locations have been recorded in one or more databases. These include activities such as hazardous waste generators or underground storage tank operators that require a permit to operate, contaminated sites such as Resource Conservation and Recovery Act (RCRA) listed sites, and sites where reportable spills of oil or hazardous materials have occurred. To obtain a perspective on the distribution of such sites along the full length of the Ohio River, the Corps collected information from all available databases. All records occurring on or within one mile of either bank of the river were selected and mapped.

2. This survey identified 3,579 mapped sites. Most sites are listed by more than one database. For example, site 950 in Pittsburgh includes records for a past leaking underground storage tank, current registration of underground tanks, and a reported spill. As expected, sites are concentrated in urban and major port areas, but numerous sites are present along the length of the river. (See Env. App. CEA Chapter 8, Health and Safety, for an overview of mapped areas, an example detail map, and records for an example site (#950).)

3. The availability of funding for redevelopment of brownfields and other former hazardous waste sites is contributing to reutilization of some formerly abandoned sites. Limited availability of undeveloped land within some areas of the floodplain further reinforces the reuse of formerly developed sites. These abandoned or underutilized sites are representative of historic urban/commercial development patterns and are an important component of many redevelopment programs. Successful redevelopment of such sites should include removal or stabilization of buried contaminants, thus contributing to reduced public health risks.

4. Spills of hazardous or toxic materials are an ongoing problem associated with commercial navigation and river-oriented industry. Activities and areas of particular concern include vessel fueling operations (including midstream), barge loading/off-loading operations, queuing areas and river reaches with heavy debris. Short to long-term impacts are associated with exposure of spills and public drinking water intakes. Spills also may damage or contaminate shoreline areas.

5. Spill records from the Emergency Response Notification System (ERNS) were collected for the period 1990 – 2000 (see Env. App. CEA Chapter 8, Health and Safety).

This database produced 1,700 non-duplicate records for the Ohio River that located the spill event by river mile. These spill events were not randomly distributed along the 981 miles of river, but, as expected, were concentrated in the major port and industrial areas. The 1,700 spill records correspond to just 56 discrete river mile (RM) point locations, ranging from a low of 4 records at Clarksville, IN (RM 605) to a high of 190 at Louisville, KY (also at RM 605). By clustering points that were close together (e.g. RM 602 – 608 for Louisville), spill events could be summarized as just 36 locations along the river. The most frequent spill locations correspond to the

- Follansbee, WV area (75 spills, RM 71-75),
- Yorkville, OH to Wheeling, WV (75 spills, RM 85-90),
- Point Pleasant, WV area (79 spills, RM 265-270),
- Kenova, WV/South Point, OH/Catlettsburg, KY area (182 spills, RM 316-318),
- Cincinnati, OH area (129 spills, RM 468-473),
- Louisville, KY area (234 spills, RM 602-608),
- Owensboro, KY (66 spills, RM 757)
- Paducah, KY (107 spills, RM 935)

5.6.2.2 Recreational Boating Accidents

1. All boating accidents for the six states along the Ohio River totaled 4,955 events for the period 1995-2001 and accounted for 8.8% of all boating accidents nationwide. Accidents occurring on the Ohio River during the same period totaled 295 records, or 4.7% of all boating accidents in the six states. For Ohio River boating accidents, collision with another vessel was the most common event, accounting for 80 accidents or 34% of the total. Other collisions (floating/sunken objects, docks, etc.) or groundings accounted for 47 events (20%), flooding/swamping, or capsizing the vessel accounted for 25 events (11%), and falling overboard or within the vessel accounted for 21 events (9%). Other types of accidents included fire/explosion (8%), sinking (7%), victims in water struck by boat or prop (4%), skier mishaps (3%), and miscellaneous other (4%).

2. The limited years of available data reveal no apparent trend in the annual average number of accidents on the Ohio River. Annual numbers vary widely, from a low of 21 in 1998 to a high of 50 in 1999. Anecdotal comments suggest that high water conditions during peak weeks of the boating season (mid-May through mid-September) significantly reduces the total amount of boating activity and may likely contribute to similar declines in number of accidents in such years. This high annual variability, combined with the relatively small number of annual accidents on the Ohio River, makes it difficult to determine any trends over a limited period of time.

3. Recreational boating activity and reported boating accidents on the Ohio River are highly concentrated on warm season weekends. The months of June through August account for 71.1% of all accidents, while May through September account for 89.7%. Saturday or Sunday accounts for 62% of all accidents.

5.6.2.2.1 Boating Accidents and Barge Traffic

1. Reported recreational boating accidents for the Ohio River from 1995 through 2001 included 9 events out of 235 that involved a commercial vessel. The 9 accidents all involved recreational boats and barge/tow combinations that were underway at the time of the accident.

2. Three of the accidents resulted in 8 fatalities, including one accident that produced 6 deaths. The principal cause of this most serious disaster was listed as restricted vision due to fog and darkness. Improper loading was listed as a secondary factor; the six victims were sharing a 16 to 18 foot open motorboat. The barge/tow was not cited for contributory factors in this case.

3. For the nine accidents, alcohol use was cited as the primary cause of three events and a secondary factor in two additional events. Careless/reckless operation and operator inexperience were each cited as the primary cause of two accidents, while machinery failure and restricted vision were each identified for one accident. Operator inattention was recorded as a secondary factor in three cases and no proper lookout (attributable to the barge operator) was recorded for two cases. Six of the nine cases occurred at night. No case indicated that crowded conditions on the waterway contributed to the accident.

5.6.2.3 Water Quality Health Risks

5.6.2.3.1 Bacteria Contamination and Monitoring

1. To protect human health associated with contact recreation, ORSANCO monitors six urban areas (Pittsburgh, Wheeling, Huntington, Cincinnati, Louisville, and Evansville) five times per month from May – October for both fecal coliform and *E. coli*. A total of 19 stations are monitored near the six urban areas. Additionally, nine water supply utilities perform analysis for fecal coliform bacteria on their raw intake water and provide these results to ORSANCO monthly, bringing the total to 28 stations monitored for fecal coliform.

2. No violations of the stream criterion to protect public drinking water supplies occurred during calendar year 2001(the latest year available). During May through October 2001, however, all six urban areas recorded one or more violations of the contact recreation standards. Of the 28 urban stations monitored, 22 stations exceeded stream criteria to protect human health associated with contact recreation.

3. Records for 2001 reflect the recent pattern for bacteriological exceedances in Ohio River urban areas. Exceedances occur annually in most urban areas and are generally associated with high flow conditions. Combined sewer overflows, leakage and overflow from sanitary sewer collection systems, and urban stormwater runoff are considered the primary sources of these biological contaminants.

5.6.2.3.2 Fish Consumption Advisories

. All six states bordering the Ohio River have consumption advisories in place for certain species of fish from the river. These advisories primarily focus on the potential

presence of certain contaminants and are derived from results of fish tissue sampling conducted by ORSANCO. An advisory committee comprised of state health and environmental quality personnel is convened to discuss the data and assess the need for fish advisories. Fish advisories are then issued, removed or modified by state agency personnel. ORSANCO also facilitates communication among the states to minimize differences in advisories issued for Ohio River fish.

5.6.2.4 Noise Impacts

As stated in section 5.6.1.4 under historic conditions, construction activity in close proximity to sensitive populations, riverfront industrial operations, and highway and rail bridges that concentrate vehicular traffic are ongoing sources of noise impacts. Regulation of construction and industrial activities minimizes most potential conflicts. However, changes in riverfront recreational and residential patterns could be impacted by pre-existing noise sources.

5.7 RECREATION AND AESTHETICS

See Environmental Appendix, CEA Chapter 9 and Exhibit C for an expanded discussion of recreation.

The Ohio River has long been the setting for a wide variety of river-based and shoreline recreational activity. Such activities have contributed to the demand for and continuing development and maintenance of a spectrum of recreation-related facilities, including boat launching ramps, riverfront parks, trail and greenway corridors, marinas and mooring facilities, and floating restaurants. More recently, riverfront settings have become popular locations for sports stadiums, museums, concert venues, casinos, on-shore dining-shopping-entertainment complexes, hotel and convention centers, and residential developments. The limits on recreational opportunities related to the Ohio River do not appear to have been reached, as further enhancement of recreation and tourism oriented facilities still figure prominently in all riverfront planning by individual communities as well as by public/private regionally focused groups along the river. Aesthetics, as a resource, is nebulous to define since it is subjective and changes with the viewer. This report combines aesthetics and recreation since these two resources are so closely related for many recreational activities. Aesthetics as a stand-alone resource, however, is not easily discussed at this level of study particularly since this study does not recommend any structures be moved to new locations. Since the recommendations contained in this report pertain only to rehabilitations and new construction in existing locations, there will be no aesthetic disruptions on a system-wide basis. A more detailed look at aesthetics will be considered at the project-level analysis when recommendations contained in this report are implemented.

5.7.1 Historic Conditions

1. Popularity of the Ohio River as a setting for recreational activity dates back to well before 1920, the beginning date for this assessment. One of the most visible early recreational uses of the Ohio River accompanied the advent of steamboat transportation in the early 19th Century, which introduced luxury travel on the Ohio River for those that could afford it. Later, some steamboats were converted for use as floating entertainment

centers, which offered dining, music, theater and vaudeville, for over a century. The last vestige of this era is the showboat *Majestic*, built in Cincinnati in 1923, (Baldwin, 1981). Now moored at the Cincinnati Public Landing, the *Majestic* still offers a summer theater series on the river.

2. Commercial steamboat transportation declined through the mid 19th century due to competition from the railroads, but the entertainment value of traveling by steamboat survived. Although expensive, vacation travel on steamboats has remained popular into the 21st century. In addition to overnight travel, numerous excursion boats began operating on the river during the 19th century and several continue to offer short dining and sightseeing trips on the river.

3. By the turn of the 20th century, individual and family oriented activities such as pleasure boating, fishing, swimming, and picnicking were all highly popular pastimes on the Ohio River. Before completion of the low-level navigation dams (1929 or earlier, depending on location), summer low water in many areas along the river revealed miles of smooth sandy beaches. On weekends, such beaches were popular sites for family outings, where people could boat, fish, swim, and picnic (Roberts, 1981).

4. As completion of the low-level dams progressed through the 1920s, several factors began to influence recreational activities on and around the river, with changes varying by location along the river. Along the heavily industrialized reaches from Pittsburgh through Wheeling, for example, steel mills, other industries, and railroad lines crowded out residential and commercial uses of the floodplains while also discharging industrial effluents to the river. The combination of pollution and restricted access eliminated most recreational activities and contributed to negative perceptions of the river's recreational potential that persisted well into the 1970s (Muller, 1989). Downstream from the industrialized reaches, acidic discharges from coal mining impaired aquatic life and rendered much of the river unusable for recreation. By contrast, significant recreational activity in the Cincinnati area persisted well into the 1930s and began to recover concurrent with improving water quality during the 1960s. Downstream from Cincinnati and Louisville, rural stretches of the river historically were less impacted by pollution and seemed to persist with less disruption.

5. The river's navigation dams have had mixed impacts on recreation patterns. The low water beaches were flooded and fisheries associated with shallow riffles became restricted to tailwater areas immediately downstream of the dams. Changes in water quality, however, have stimulated the most dramatic impacts to recreational activities. Coordinated efforts to clean up the Ohio River, beginning with the establishment of ORSANCO in 1948 and continuing with the implementation of the Clean Water Act and other important environmental legislation, have contributed to reestablishment of traditional recreational uses of the river, a trend that began in the mid-1960s. This period roughly corresponds to the development of the high lift lock and dam projects that replaced the earlier wicket dams Thus, particularly for the upper and middle reaches of the river, the recovery and expansion of river oriented recreation occurred in the relatively stable environment of the long pools behind the high lift dams rather than in the free-flowing river.

5.7.2 Current Recreational Practices

1. Currently, the Ohio River is a popular setting for a broad spectrum of recreational activities. People living in counties adjacent to the river tend to view this resource as an important contributor to their quality of life and a significant portion of their recreational activity is oriented to the river. In urban areas, interests in the river have contributed to the provision of a wider range of opportunities, including riverfront parks and landings, large marinas, special events, and riverfront dining, shopping, and related entertainments. Almost every large and small community along the river provides some type of facility and event oriented to the river. Urban, small town, and rural settings along the river also serve as regional recreation and tourism destinations.

2. Events that draw large crowds and activities with large numbers participating attract a lot of attention, but solitude and quiet relaxation also are some of the most important values associated with recreation on the Ohio River. People living in urban areas especially appear to value the river as a convenient way to escape and relax.

3. Recreational activities on the Ohio River have grown steadily concurrent with improved water quality and economic prosperity. The primary factors affecting current trends in recreational activity are acceptable water quality, accessibility, maintenance of recreation facilities, and expanding choices.

4. Existing parks and access facilities along the urban pools are heavily used, and new facilities are readily discovered and utilized. Access points and other resources in some rural areas appear to be less crowded. A variety of public agencies and private organizations are actively engaged in development of new riverfront parks, greenways, trailways, boating access, and mixed use urban riverfront projects.

5. The most heavily used areas along the river also are those areas most directly impacted by operation and maintenance of the navigation system. To reflect influences of the navigation system in the context of broad economic forces, as well as to maintain consistency with the scope of other chapters (e.g. Land Use, Health and Safety), counties adjacent to the Ohio River mainstem were defined as the geographic focus for impacts related to recreational activities. Three variables that contribute significantly to recreational activities in a local or regional setting were explored: opportunity, availability, and experience.

6. Employment and income statistics are indicative of socioeconomic trends that contribute to recreational opportunity within a given population. For example, a population with better than average employment and income has more opportunity for recreational activity than a population that is less affluent. Over time, population growth in combination with economic prosperity will contribute to expanding opportunities for recreational activity.

7. Accessibility generally refers to ease of access to a given recreational resource. Individuals living close to the Ohio River have easier access than individuals living an hour's travel time away. The presence of boat launch ramps, community parks, or public access to shoreline fishing sites provides improved access in comparison to areas without

such facilities. The type of facility provided may also differentially benefit certain groups (e.g., boat ramps likely provide little value to hiking/biking interests).

8. The quality of experiences directly influences future recreational choices. Not only are individuals more likely to repeat pleasurable recreational experiences, but they are likely to encourage others through word-of-mouth. The collective activity and experiences of a given population thus can provide a good indicator of both future activity and how the population will respond to changes in the recreational resource.

9. Over the past 30 years or more, the popularity of the Ohio River as a setting for recreational activities has experienced tremendous growth in numbers of participants and scope of activities. Most readily available studies of Ohio River recreation have focused on boating and fishing activities. These studies include recent trends that may be applicable to analysis of the broader spectrum of recreational activities.

5.7.2.1 Recreational Boat Lockage Data

1. The Corps of Engineers maintains records of all boat traffic that utilizes its locks on the Ohio River, including recreational vessels. Lockage records do not directly reflect all boating activity on the river because the relatively large size of Ohio River pools and general availability of access and boater services makes 'same pool' boating a feasible option.

2. Total recreational boat lockages at all 20 Ohio River lock and dam projects for the past six years of record indicate that the lock receiving the greatest recreational use is Meldahl, with Markland a close second. Cincinnati is located approximately midway between these projects and the population base there likely contributes to the high recreational use of these locks. By contrast, McAlpine lock and dam is located in downtown Louisville, apparently allowing boaters to launch either above or below the dam and thus minimize use of these locks. The high numbers of lockages at the upper four projects (Emsworth, Dashields, Montgomery, and New Cumberland) reflect boating activity in the Pittsburgh area. Pools at these locations are also much shorter than downstream pools, which contributes to more frequent lockages. Lockage patterns also generally reflect annual variations in recreational boating opportunity associated with weather and water conditions during the May-September peak season.

3. When aggregated for the entire river and tracked for the long term, recreational lockages reflected a steady growth trend for boating on the Ohio River from 1980 through 1988 and almost no growth from 1988 through 2001. The rapid growth of lockage activity from 1980 to 1988 may reflect renewed interest due to improved water quality while the trend from 1988 to 2001 could be influenced by a variety of factors, including annual variations in river water levels, changes in boating travel patterns, or improved availability of launch ramps (which could reduce the need to lock through from available ramps to preferred pools). The latter trend may also reflect that boaters in the region are aware of opportunities on the river and the level of interest has stabilized.

5.7.2.2 Studies of Boat Registrations and Boat Owners

1. Recent annual boat registration data (1996-2001) for states in the Ohio River region generally reflect both the national average boat registrations per capita and the recent national trend towards a slower rate of growth, with an average annual growth for the region of 1.1 percent during the past six years. Growth rates for individual states range from a low of –0.04% for Indiana to a high of 2.8% annually for West Virginia.

2. The Ohio Department of Natural Resources, Division of Watercraft (OHDW) has completed two boating studies that help to illustrate boater activity on the Ohio River (Husak 1999 and ODNR 2003). Although details of these studies are found in CEA Chapter 9, major findings applicable to the Ohio River are presented below:

- The 1999 study showed that of the all boating trips within Ohio, about 8.3 percent occurred on the Ohio River during the study period.
- On the Ohio River, 50% of overnight boats traveled alone while 50% traveled in small groups of two to five boats. The most important destination features for overnight travel include 'suitable draft for boat' and experiencing a 'back to nature atmosphere'.
- Of Ohio boaters in general, Ohio River boaters were least likely to report a need for speed limits with about 58 percent reporting 'no need'. Those reporting 'no need' on other waterways ranged from 15 to 52 percent.
- Ohio River boaters reported a lower satisfaction with the availability of launch ramps compared to boaters using other Ohio waterways.
- Finally, proportionally more Ohio River boaters (48.3%) reported negative impacts from accumulation of silt and natural debris in the waterways.

5.7.2.3 Boating/Fishing Studies

1. The most recent Ohio River boating/fishing studies for which data are available were a 1992-1993 survey conducted by the Ohio DNR, Division of Wildlife (Schell et al., 1996), a 1992 survey near Pittsburgh (TES, Inc. 1996), and a 1981 survey by the West Virginia DNR (Pierce et al. 1983).

2. The primary objective of both the Ohio DNR and West Virginia DNR surveys was to provide direction and prioritization in developing fisheries strategies, resource protection, recreational facilities development, and public perceptions of the resource. Both studies employed aerial and shoreline surveys and were coordinated to insure comparability of findings. Consequently, comparisons can be made for several types of activity on the eight pools addressed by both surveys. One finding of both studies was related to historic water quality and indicated that fishing may require a somewhat higher level of water quality than pleasure boating. Boating and fishing data collected by the ODNR survey in 1993 suggests that urban boaters may be somewhat less likely to include

fishing in their boating activities. The popularity of fishing in the Meldahl pool, located upstream from Cincinnati, may be due in part to boat anglers desire to avoid crowds.

3. The study near Pittsburgh examined and interviewed recreationists on 40 miles of the Ohio River, 14.5 miles on the Allegheny, and 23.8 miles on the Monongahela. The purpose of this study was to characterize and quantify the various recreational uses of the rivers in the study area for planning and managing the future recreational development of the rivers. Among the study's findings were that the relative proportion of boat fishing activity in the Pittsburgh study, 12.7 percent of all boating, may be comparable to the 14.5 percent found on Cincinnati's urban pool by the ODNR study in 1993.

4. Recreational activity on rivers in the Pittsburgh study area was strongly influenced by seasonal weather with about 67 percent of all boating and 55 percent of all fishing activity occurring during the June-August summer season. Despite fairly high catch rates averaging just over three fish per hour, anglers near Pittsburgh generally rated fishing quality as 'poor' (about 38%) or 'fair' (28%), primarily due to water quality concerns.

5.7.2.4 Riverfront Enhancement Trends.

1. Measurable improvements in the water quality of the Ohio River mainstem have led to the rediscovery of the river as an asset to communities along the entire river corridor. During the earlier water quality recovery phase (1970s and 1980s), specific sites began to be developed for recreation and entertainment, for example, riverfront parks, major league stadiums, and riverboat restaurants. Within the past decade, however, riverfront projects have become much more comprehensive in scope. Large and small-scale efforts to integrate residential and commercial development, shoreline and river recreation, heritage tourism, and ecological protection/restoration are underway in many communities along the Ohio mainstem.

2. All three of the river's major metropolitan areas have organizations dedicated to regional visions for the river corridor:

- River Fields, Inc. (www.riverfields.org), the oldest such organization, promotes management, protection and development of land and water resources along both sides of a 50-mile reach of the river near Louisville.

- The Ohio River Way (www.ohioriverway.org), based in Cincinnati, focuses on a 150-mile reach of the river from Maysville in Mason County, KY (RM 408-409) to Madison in Jefferson County, IN (RM 558-559).

- The Pittsburgh Riverlife Task Force (www.pittsburghriverlife.org) was founded in 1999 to develop a compelling vision for the city's waterfront, an area encompassing portions of the Ohio, Allegheny and Monongahela rivers. Concurrently, the Western Pennsylvania Field Institute (www.wpfi.org) supports a program promoting outdoor recreation of all types on and along Emsworth Pool (Ohio RM 0-6.2).

3. Several smaller communities along the river have developed comprehensive planning processes or have implemented plans that combine recreation, heritage tourism

and economic growth. Such efforts have occurred in Wheeling, WV, Marietta, OH, Evansville, IN, Paducah, KY and Southwestern Illinois. Further, many other smaller communities along the river are developing docking facilities, rejuvenating their downtowns, and hosting river-based festivals focusing on regional music, art, food, and other local attractions (e.g., the Superman festival in Metropolis, IL). Widespread Internet access has become increasingly important in publicizing recreation and entertainment offerings of smaller river communities.

4. The Ohio River Scenic Byway (www.byways.org/browse/byways/2286) connects communities and points of interest along the 943-mile north bank of the Ohio mainstem through the states of Ohio, Indiana, and Illinois. Like other routes in the National Scenic Byways system, the Ohio River Scenic Byway markets and promotes all types of recreational, natural, scenic, and cultural features within at least one to two miles of the route.

5. The growth and diversification of recreational activities on the Ohio River have created demands for a variety of support facilities and services. Informal and qualitative data suggest that steady growth is occurring in riverfront dining, camping, marinas, shopping, launching ramps, parks, and related services in response to this demand. Numbers of marinas and public boat launching ramps can be tracked from Corps of Engineers' Navigation Charts for the Ohio River. A review of these charts has shown a 200% growth in the number of ramps between 1976 and 2003.

5.8 TRAFFIC AND TRANSPORTATION

See Environmental Appendix, CEA Chapter 10 for an expanded discussion of Ohio River transportation.

This section considers development of traffic and transportation, especially river related aspects, along the Ohio River. As emphasized in Section 4, the Ohio River is an important artery of the nation's inland waterway system, providing for commercial navigation in the eastern third of the country. To reiterate, the entire Ohio River navigation system consists of the Ohio mainstem and navigable portions of eight tributaries, including the Allegheny, Monongahela, Kanawha, Big Sandy, Kentucky, Green, Cumberland, and Tennessee Rivers. The mainstem serves as a collector of system traffic for distribution points within and outside the Ohio basin. Through interconnections with the Mississippi River and its tributaries, the Ohio River navigation system also has access to midwestern states and deep-draft ports on the Great Lakes and the Gulf Coast. While this section focuses primarily on water transportation, it also summarizes intermodal links with the Ohio River that extend the influence of commerce on the Ohio mainstem far beyond the Ohio basin.

5.8.1 Historic Conditions

Section 5.3 (Land Use) related much of the history of land use patterns to the Ohio River as a primary transportation mode. Therefore, information presented in section 5.3 is summarized herein.

5.8.1.1 Transportation Patterns during the 19th and Early 20th Century

1. Bigham (1998) refers to the Ohio mainstem as the nation's first interstate highway, bringing goods and people to the first western frontier. During the early decades of settlement, the Ohio River provided the primary corridor of transportation, both for immigration of new settlers and for the shipment of regional products; consequently, initial settlements within the region tended to cluster along the Ohio River mainstem. Some early riverfront settlements subsequently prospered as hubs or service centers to interior regions accessed overland by horse and wagon, thus representing an early form of intermodal transportation.

2. Development of the Ohio River in the 1800s was limited to the removal of snags, completion of the initial canal and locks around the Falls of the Ohio in 1833, and completion of the first wicket dam at Davis Island, near Pittsburgh in 1885. Inland canals provided the first significant alternative or supplement to river transport, beginning in 1825 with completion of the Erie Canal from Buffalo to New York City. In contrast to conditions of inland rivers of that era, canals provided nearly year-round transportation and the ability to ship products more directly to eastern markets instead of overland from Upper Ohio, Allegheny, or Monongahela ports. On balance, canal development probably supplemented river traffic more than it competed with or replaced river traffic. Steamboats hauled goods to canal terminals on the Ohio River, creating another early form of multimodality.

3. Railroads provided a far more significant level of competition to river transport than did canals and quickly became the primary means of commercial transportation in the region. They provided true year-round transport capabilities, greatly reduced transport times, and could be quickly built to serve any point-to-point opportunity. The first railroad in the Middle Ohio River Valley was completed in the 1840s, connecting Lake Erie with the Ohio River. By 1855, there were 1247 miles of track in the Ohio Valley, virtually saturating rail transport opportunities in the region. (Carlisle & Mulligan 2001). Railroads almost immediately rendered canals obsolete, sometimes laying track beside or over the abandoned canals.

4. Commercial river transport declined at a slow but steady pace in competition with railroads. Inland cities with good rail connections grew substantially. To a large degree, the early river port towns along the Ohio River either prospered or perished with the railroads, depending on their ability to attract rail service. Subsequently, further prosperity came to most towns able to establish railroad bridges across the Ohio River.

5. The latter decades of the 19th century and early decades of the 20th century included the period of heavy industrial development along the middle and upper Ohio River. This development centered on the iron and steel industry in Pittsburgh, with its convergence of raw materials, coal, river water, and rail and river transportation to move materials and produce into and out of the region. During this time, the Ohio River stimulated a variety of transportation and technological strategies that pushed expansion westward and added to the nation's overall prosperity (Bigham 1998).

5.8.2 Transportation Patterns from the 1920s to the Present

1. Commerce on the river grew steadily through the 1930s and 1940s while development of diesel towboats and larger barges created opportunities for larger scale, more efficient movement of commodities. Designed for about 15 million tons of commerce annually, the old locks and dams handled more than 70 million tons in 1954; in addition, traffic moving upstream on the Ohio had nearly equaled that moving downstream. By this time, construction of Emsworth, Dashields, Montgomery and Gallipolis L&Ds during the 1930s had already replaced some old locks and wicket dams on the upper river.

2. Plans to improve system efficiency and accommodate the larger tugs and barges called for reducing the number of dams by building larger dams, referred to as "high-lift" because they created greater pool elevation differentials. Along with the high-lift dams, the Corps added locks with larger chambers adequate to pass larger tows. (Details of the modernization plan, which will be completed when Olmsted becomes operational, are included in Section 4.3.)

3. During the 20th century era of sustained urban growth, rapidly growing cities expanded beyond the river floodplain to higher ground, utilizing mass transit (light rail, bus) and automobiles to connect their expanding fringes with urban riverfront cores.

5.8.3 Current Conditions and Trends

5.8.3.1 Locks and Dams

5.8.3.1.1 Current Design

1. The current configuration of the river, as modified by the pool levels behind the system of high-lift dams, generally provides for navigation of commercial tows as long as 1200' long by 108' wide, although some tows on the lowermost reaches of the Ohio operate in a double-wide configuration of 30 barges (5 long x 6 wide), typical of the larger tows on the lower Mississippi River. Section 4.4 includes additional detail of barge configurations and navigation conditions in the lower river.

2. Section 4.4 also presents details concerning the three broad classifications of the current lock and dam facilities: 1) the 60+ year old upper three structures (Emsworth, Dashields, and Montgomery L&Ds) just downstream of Pittsburgh, 2) the thirteen modernized lock and dam structures constructed between 1954 and 1979, plus R.C. Byrd L&D, where new locks were completed in 1995, and 3) the locks and dams with dual 1200'x110' lock chambers which include Smithland, McAlpine, and Olmsted (under construction). WRDA 2000 Sections 101 (14) and (15) authorized the Corps to extend the current auxiliary chamber at J.T. Myers and Greenup L/D from 600 feet to 1200 feet. These efforts are currently in design stage.

3. Significant delays occurring at various Ohio River locks and dams are linked to lock maintenance closures rather than a lack of total capacity to efficiently accommodate traffic. Lock maintenance closures are scheduled, and shippers receive closure notices well in advance, thereby allowing them to adjust deliveries. Scheduled maintenance

closures typically last from 30 to 60 days and occur mostly on a five- to ten-year maintenance cycle. Unscheduled chamber closures can occur with little or no advance notice, usually when a component of the lock fails, forcing chamber closure. In these situations, shippers have few options other than wait their turn to transit through the auxiliary lock. Both types of closures are disruptive to traffic on the river and result in build up of tows (queuing) upstream and downstream of the L&D. Often, tows may have to wait several days in queue before their turn to lock through the auxiliary chamber and continue their trip.

5.8.3.1.2 Commodities Transported

1. Inland waterways carry 11 percent of commodities nationwide, but account for only 1 percent of freight costs, making inland shipping the cheapest freight mode in terms of average transportation cost per ton-mile (Wilson 2001, cited in Transportation Research Board 2002). Barge transportation also is the most energy efficient mode for carrying large quantities of bulk commodities. A typical jumbo barge (195' x 35') can transport as much coal or grain as 15 rail cars for one-fourth the energy per ton-mile (Huntington 2003). A typical 15 barge Ohio River tow carrying 22,500 tons is equivalent to 255 railcars (two 25 unit trains) or 865 semi-trucks.

2. Commodities transported on the Ohio River system are the products of coal mines, petroleum refiners, stone quarries, cement plants and farms and raw materials for construction companies, steel mills, electric utilities, paper plants, aluminum manufacturers and chemical companies – the foundation of the region's economy. Commodity traffic flow at a given lock and dam is largely determined by its geographic location. The commodity mix consequently influences barge type and tow configuration (USACE 2000).

3. Ohio River mainstem traffic is dominated by coal transport although market patterns have changed in the past several years. There was a 2.8 percent annual increase in coal traffic from 1965 through 2001, but coal traffic slightly declined (-0.3percent) from 1991 through 2001. To some extent, changes in the coal export market account for this decline, which has resulted from increasing competition from other exporting countries and the movement away from coal for environmental reasons.

4. In 2001, 87 percent of traffic within the Ohio River system moved on the mainstem as compared with the entire system, which includes navigable tributaries. Since 1990, growth on the Ohio mainstem has slowed somewhat from its rapid 1940-1990 pace, when it averaged 4.2 percent annual growth. The annual growth rate for the mainstem from 1990 to 2001 was 0.7 percent. Since 1996, total mainstem traffic has stabilized around 240 million tons per year.

5. The dominance of electric utility coal transport on the Ohio River and attention focused on coal by the government and the public are reflected in the Corps' most recent traffic demand forecasts. Because coal is such a dominant factor on the Ohio River, traffic forecasts place special emphasis on utility coal and the sorbent materials (lime and limestone) used for coal desulfurization. While other commodities and barge-served markets face uncertainty, none faces a more uncertain future than coal. Deregulation is affecting the electric utility industry, but environmental regulations, especially regarding

air quality, will be the dominant factor affecting future coal utilization and sourcing by the electric utility industry.

6. Recent trends in the other commodities reflect growth rates exceeding 4.0 percent annually in aggregates, grain, and iron. Aggregates consist primarily of crushed limestone, sand and gravel, and building stone. These comprised the second largest commodity group on the Ohio mainstem in 2001, accounting for 16.9 percent of the traffic. Grain traffic, consisting primarily of corn, wheat, and soybeans, composed 7.4 percent of Ohio mainstem traffic in 2001. In 2000, approximately 71 percent of the grain traffic on the Ohio River system was outbound, primarily for export markets.

7. The iron and steel industry has undergone massive changes in recent decades. Within the Ohio River system, only four integrated steel mills remain in operation. Most iron ore and iron and steel products currently moving on the Ohio River system move from Gulf Coast ports to the remaining integrated mills on the Ohio River system. Detailed traffic demand forecasts for all commodities are included in Attachment 3 to the SIP/PEIS Economics Appendix (USACE-Huntington 2003).

5.8.3.2 Rail

Rail transportation has been important in the growth of the Ohio River valley and is directly related to the availability of raw materials and natural resource commodities. As mentioned previously, rail transportation provides year round operability, which is an advantage to commerce. In some parts of the Ohio River basin, the current rail system lacks the necessary connections with other lines for cost effective transport of goods ,while in other parts rail transportation has been successfully integrated into an intermodal system. Information from the U.S. Department of Transportation's Freight Analysis Framework (FAF) indicated that in the six states bounded by the Ohio River, the amount of freight transported by rail is expected to remain constant or decrease slightly through 2020. West Virginia was the exception where rail transportation of goods is expected to remain dominant through 2020. The FAF also found that 50% of the river terminals have rail access but it is not entirely utilized due to lack of efficient connections.

5.8.3.3 Highway

Highway transportation consists of overland movement of goods and commodities (i.e., in trucks). The higher the value of the commodity, the longer the distances that the commodity is trucked. Raw materials and natural resources are economically transported in bulk via water transport. However, in many instances, highway transportation is utilized to transport the commodities to river ports and terminals and to other facilities after water transport has occurred.

5.8.3.3.1 Historical Conditions

Until the 1960s, rail and river transport were the main sources of transportation of goods and services. With the advent of the National Highway System, truck transportation became more feasible. Goods from river terminals and ports are transferred to other locations via truck transport for distribution.

5.8.3.3.2 Recent Conditions and Trends

1. The Appalachian Development Highway System has developed several highway corridors within the Appalachian region that provide access across and parallel to the Ohio River in West Virginia, Kentucky and Ohio and connections with other large interstate systems. The Appalachian Regional Commission currently provides grants and other monies to promote feasibility studies and construction of intermodal transportation networks, access roads from communities to the existing highway system and completion of the corridor system in Appalachia.

2. Information from the U.S. Department of Transportation's Freight Analysis Framework indicated that highway transportation of freight (i.e., by truck) is the leading mode of transport in the six Ohio River bounded states except in the state of West Virginia. In the agricultural regions of Ohio, Illinois and Indiana, grain transport is conveyed via trucks 95% of the time to other modes of transportation such as river terminals and ports. In the coal regions of Kentucky and West Virginia, over 40% of the overland coal transported to river terminals is accomplished by truck.

5.9 SOCIOECONOMIC PROFILE

See Environmental Appendix, CEA Chapter 11 for an expanded discussion of socioeconomic and environmental justice data for the Ohio River Corridor.

5.9.1 Demographics

5.9.1.1 Historical Conditions

1. Along the Ohio River, there are eight Metropolitan Statistical Areas (MSAs), each encompassing major population centers. The MSAs are: Pittsburgh, Steubenville/Weirton, Wheeling, Parkersburg/Marietta, Huntington/Ashland, Cincinnati Consolidated, Louisville, and Evansville. In addition, there are rural counties adjacent to the river but outside of these MSAs.

2. MSAs along the Ohio River upstream of Cincinnati experienced overall population growth from 1900 through about 1960. Most rural counties upstream of Cincinnati experienced population declines during the same period.

3. Beginning about Cincinnati and continuing downstream to Evansville, there was a consistent pattern of population growth within MSAs and population declines in rural counties over the first part of the 20th century. Rural counties downstream of Evansville experienced population declines throughout this period.

5.9.1.2 Recent Conditions and Trends

1. From about 1960 and continuing through 2000, MSAs upstream of Cincinnati all experienced population declines. With the exception of the area between Parkersburg-

Marietta and Huntington-Ashland, populations in rural counties also declined through this period.

2. Beginning about Cincinnati and continuing downstream through Evansville, total population, both within MSAs and in rural areas, grew overall in the last half of the 20th century. Rural counties downstream of Evansville experience a general decline in population during the same time frame.

3. In the two largest MSAs (Pittsburgh and Cincinnati), a noticeable pattern developed in the last part of this century. In both areas, populations in the central or core county declined. In both instances, there was evidence of population movement from the center to outer parts of the MSA. In Pittsburgh, this out-movement occurred in spite of overall population decline for the entire MSA.

5.9.2 Environmental Justice

1. Environmental justice (EJ) addresses the issue of disproportionate impacts on minority and economically disadvantaged populations. Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," provides that "each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations (EO12898)."

2. The geographic focus for EJ impacts includes those areas most directly impacted by operation and maintenance of the navigation system. In order to reflect influences of the navigation system in the context of broader business and economic forces, as well as to maintain consistency with the scope of other chapters (Land Use, Health and Safety, etc.), counties adjacent to the Ohio River mainstem are defined as the geographic focus for EJ impacts. Where such counties are part of a Census-defined Metropolitan Statistical Area (MSA), all counties in the MSA are included in the geographic focus for EJ impacts.

3. A series of 12 public scoping meetings was held during Summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. For a detailed discussion of the public scoping process, see the Environmental Appendix, Cumulative Effects Assessment Report Chapter 2 and the CEA Exhibit A on Scoping.

4. Numerous federal agencies have published guidelines addressing EJ issues. Guidance from the General Services Administration (Fact Sheet, GSA) notes that "NEPA provides a major planning context in which EJ issues can be addressed, though such issues should be considered under other environmental review authorities as well (e.g., the National Historic Preservation Act and the Endangered Species Act). The Presidential Memorandum (Executive Order 12898) identifies four important ways to consider EJ under NEPA, which are summarized in the CEQ's EJ guidance (CEQ 1997) as follows:

- "Each Federal agency should analyze the environmental effects, including human health, economic, and social effects of Federal actions, including effects on minority populations, low-income populations, and Indian tribes, when such analysis is required by NEPA.

- Mitigation measures identified as part of an environmental assessment (EA), a finding of no significant impact (FONSI), an environmental impact statement (EIS), or a record of decision (ROD), should, whenever feasible, address significant and adverse environmental effects of proposed Federal actions on minority populations, low-income populations, and Indian tribes.

- Each Federal agency must provide opportunities for effective community participation in the NEPA process, including identifying potential effects and mitigation measures in consultation with affected communities and improving the accessibility of public meetings, crucial documents, and notices.

- Review of NEPA compliance (such as EPA's review under Section 309 of the Clean Air Act) must ensure that the lead agency preparing NEPA analyses and documentation has appropriately analyzed environmental effects on minority populations, low-income populations, or Indian tribes, including human health, social, and economic effects."

5. CEQ's guidance outlines several principles that should be addressed in the course of NEPA review to ensure consideration of EJ, which can be paraphrased (from Fact Sheet, GSA) as follows:

- Consider the human composition of the affected area - that is, its population and how it is used by human communities, and determine whether any such communities are characterized by low-income levels or high-minority composition. If so, determine whether there may be disproportionately high and adverse effects on such populations.

- Consider not only direct impacts on the health and environmental quality of EJ communities, but indirect, multiple, and cumulative effects as well, including effects that are not within the control of or subject to discretionary actions of the reviewing agency.

- Recognize that the cultural, social, occupational, historical, and economic characteristics of an EJ community may amplify the environmental effects of an action. Such a population may be more sensitive to such effects and less resilient in adapting to them, than another community.

- Implement effective public participation strategies that seek to overcome linguistic, cultural, institutional, geographic and other barriers to meaningful participation, and that include active outreach.

6. The Ohio River region has very few counties that exceed state averages for minority populations. In many counties, the percent minority population is only 20 or 30 percent of the state average. Counties that do exceed the state average are generally metropolitan centers such as Cincinnati in Hamilton County, Ohio. Rural counties with above average minority populations include Pulaski County, Illinois; and Hardin, Mason, Meade and Union Counties, Kentucky.

7. Census records were also searched for Native American populations. Through 1980, state and county records identified very few individuals who identified themselves as Native American. The 1990 and 2000 Census appear to be identifying slightly larger populations, which may be the result of more sensitive measuring procedures.

8. Census records for 1970, 1980, 1990 and 1995 were reviewed for people of all ages in poverty, based on Census definitions for the periods studied. Counties were identified for occurrence of high poverty rates if the percent in poverty exceeded 1.5 times the state average or 1.5 times the regional average (average poverty rate for the six state region) for any two of the four periods measured. Counties that exceed twice the state or regional average are also noted. Statewide poverty rates for Kentucky and West Virginia in 1970 exceeded 1.5 times the regional average. Exceedance of poverty levels (state or regional) by 1.5 times was selected as an evaluation factor by the study team to indicate counties in which poverty would be considered severe.

9. Per capita incomes provide an alternative to Census poverty rates for comparison of states, counties and other subregions. Per capita incomes are calculated annually by the Bureau of Economic Analysis (BEA). For the six state region, the population weighted per capita income in 2002 represented 0.981 percent of the national per capita. All states in the region show fairly stable maintenance of their income status relative to the national average, with four states gaining, Ohio essentially unchanged, and West Virginia showing slight decline. Individually, Illinois and Pennsylvania consistently rank among states with the highest per capita incomes, Ohio steadily represents the midpoint among states, and Indiana represents the point at which 2/3rds of the states have higher per capita incomes. Despite significant gains for the past two decades, Kentucky remains in the bottom tier of states while West Virginia's declining incomes keep it very near the bottom for all states. Counties with higher than average per capita incomes along the Ohio River are almost exclusively associated with major urban centers. Of the 5 counties with per capita incomes above the national average, 3 are the core counties for the cities of Pittsburgh, Cincinnati, and Louisville while 2 are adjacent counties within the MSAs of Cincinnati and Louisville.

5.10 CULTURAL RESOURCES

See Environmental Appendix, CEA Chapter 12 for an expanded discussion of cultural resources within the Ohio River Corridor.

5.10.1 Past Conditions

Cultural resources along the Ohio River are rich and varied, reflecting human occupation and significant events in the Ohio Valley over many centuries. Both the prehistoric and historic cultural resources of the Ohio River point to the central role of the river as a transportation artery in sustaining permanent settlements. In both prehistoric and

historic times, human settlements developed along the Ohio River and its tributaries because its floodplains offered rich soils and the river offered food, water and opportunities for trade. Later, the Ohio River and its tributaries were used in relation to early industries, river transportation, and trade routes.

5.10.1.1 Prehistoric Cultural Resources

1. Aboriginal peoples have occupied the Ohio Valley for thousands of years. The earliest known dates for human occupation occur in the upper Ohio Valley where the archaeological records indicates human habitation at least 16,000 years ago (Carlisle and Adovasio, 1982). The prehistoric periods of human occupation of the Ohio Valley are listed in **Table 5-1** through the period of direct contact with Europeans.

TABLE 5-1
Prehistoric Periods through Contact Period in the Ohio Valley

Period	Dates	Hallmarks of Period
Paleoindian	11,000 – 9,000 BP	Highly mobile hunter-gatherers; primarily used stone tools. Clovis (fluted projectile) point is diagnostic.
Archaic	9,500 – 2,500 BP	Divided into early, middle, and late Archaic, with periods distinguished primarily by stone tools, the introduction of horticulture, and changes in burial practices and social structure. Early Archaic is characterized by highly mobile small bands of people, primarily exploiting watercourses.
Woodland	2,500 BP – AD 1650	Effects on the landscape were dramatic due to introduction of agriculture. Early Woodland associated with Adena culture, marked by use of pottery and construction of conical interment mounds. Middle Woodland included socioeconomic integration across regional boundaries via trade networks. Hopewell culture of Middle Woodland was characterized by elaborate geometric earthworks. Late Woodland was associated with large, densely occupied villages on high terraces overlooking the major rivers.
Late Prehistoric	AD 900-1650	Encompasses Fort Ancient, Mississippian cultures, and Late prehistoric occupations leading up to the period of European contact. These cultures were built on a very effective subsistence base. A relatively high density of Fort Ancient sites

		has been recorded in the middle Ohio River Valley.
Contact	AD 1500-1800	By early 16th c., the Ohio River Valley was populated by several sedentary aboriginal groups. It is assumed that even before European contact, human presence in the New World had affected the balance of the ecological system. The Fur Trade Wars (c. 1630-1680) dramatically altered distribution of animals and the Native American population.
SOURCE: *USFWS. 2000. Ohio River Islands National Wildlife Refuge – Draft Comprehensive Conservation Plan and Environmental Assessment., Northeast Region Office, Hadley, MA.*		

2. In addition to sites along the Ohio River, prehistoric artifacts have been found on Blennerhassett Island near Parkersburg, WV, and on other Ohio River islands. A 1998 archaeological and geological assessment of the Ohio River Islands National Wildlife Refuge classified the islands into three different types with regard to cultural resources: 1) islands with sediments having recent origins not likely to contain prehistoric archaeological sites; 2) islands with Holocene sediments likely to contain historic archaeological sites close to the surface and deeply buried prehistoric sites; and 3) islands which contain a core area of Pleistocene sediments overlaid by shallow Holocene age sediments, which are likely to contain prehistoric and historic resources closer to the surface (Diamanti 1998). Information on island formation is relevant to what kinds of prehistoric sites could exist on individual islands.

5.10.1.2. Historic Cultural Resources

1. Archaeologists have worked to reconstruct the cultural and historical threads that knit together the native cultures of the Late Prehistoric and early historic periods in the Ohio River Valley with the more familiar named tribes associated with the historic contact period. The Late Prehistoric peoples of the Fort Ancient Tradition, for example, were once numerous in the Ohio River Valley. However, the rare historical and even more limited archaeological data for the immediately succeeding Protohistoric period, just prior to the time of the first contacts between Native Americans and Europeans, indicate that by A.D. 1650-1700 few Native Americans permanently resided in the Upper Ohio River Valley. In fact, early European explorers and Euro-American settlers coming to the Ohio Valley in the mid to late 18th century found few Native Americans who had been long-time residents of the region. Only small hunting camps and a few villages were found. Hunting parties ranged throughout the area as wild game abounded. Near the headwaters of the upper Ohio, now Pittsburgh, early European surveyors, traders, and settlers encountered members of the Seneca, Delaware, and Shawnee tribes who used the area during hunting expeditions.

2. As the result of the initial exposure to Europeans and diseases from which the native peoples had no natural immunity, all these tribes suffered from disease during the 18th century, which not only disrupted their traditional way of life but also reduced their ability to resist incursions by European settlers (Carlisle and Mulligan, 2001).

3. Islands comprising the upper part of the Ohio River Islands National Wildlife Refuge figure prominently in the early explorers' accounts of prehistoric and contemporary Indians, George Washington's surveying expeditions, the settling of the Ohio River by pioneers and traders, strategic battles during the Civil War, and river exploitation for navigation and industry. Many islands were large enough to be permanently settled or industrialized. For example, Neville Island, about five miles downstream from Pittsburgh, became an active industrial site during the late 1800s.

4. Prehistoric mounds and mound complexes are important features of Ohio River archaeology. As early as 1780, a military party noted the large mounds at the mouth of the Muskingum River, at the site of the future Marietta, Ohio (Carlisle and Mulligan, 2001). Prehistoric mounds and mound complexes also once stood at the location of many other Ohio cities including Circleville, Chillicothe, and Cincinnati, though most were ploughed away in the early days of settlement (Jakle, 1977:71). Extant Ohio River mounds listed by the U.S. National Park Service as National Historic Landmarks include Grave Creek Mound (Moundsville, West Virginia), which dates to 500 B.C. representing the Adena culture and Angel Mounds (near Evansville, Indiana), which date to 1000-1600 A.D. representing the northeastern most extension of the Mississippian culture.

5. During the 18th century various explanations to account for Native American artifacts, trails, and earthen mounds were developed and debated. The architectural complexity and sophistication of the mounds and the numerous abandoned sites across the landscape provided a sharp contrast to the simpler, then current Native American condition, which was interpreted to be the result of a cultural disjunction. Early explorers and settlers were unaware that the comparatively simple bands of migratory native hunters and horticulturists of their own day were the products of more than a century of cultural upheaval, dissolution, and widespread geographical relocation that had been precipitated by the development of sustained European settlement on the eastern seaboard beginning in 1607 and by related socio-political changes within other Native American cultures (Carlisle and Mulligan, 2001).

6. French and British fur traders frequented the Ohio Valley early in the 18th century, but permanent occupation by Europeans did not begin until the mid-18th century when a few isolated military outposts were established in the valley. Three major factors delayed extensive settlement in the Ohio Valley during much of the 18th century: larger ongoing European political struggles; nearly constant hostility between settlers and Native Americans; and the American colonists' struggle for independence from Great Britain. Several cities along the lower Ohio River were founded by the late 1700's including Louisville in 1779 at the Falls of the Ohio, the most significant break in navigation on the river.

7. Following the Treaty of Paris (1783), formally ending the American Revolution, the Land Ordinance of 1785 provided for the administration and subdivision of land in the Northwest Territory, which consisted of land north of the Ohio River, west of Pennsylvania and east of the Mississippi, including all of present-day Ohio, Indiana, and Illinois and parts of Michigan and Wisconsin. Following the Land (Northwest) Ordinance, several important towns and cities were founded in the upper and middle Ohio Valley, including East Liverpool (1797), Steubenville (1798), Marietta (1788) and Cincinnati (1788) – all in Ohio. Wheeling, West Virginia, had been settled somewhat earlier (1770s),

while the communities of Parkersburg and Huntington, West Virginia, both remained small until well into the 19th century. The search for good agricultural land was the major impetus to westward migration and settlement of the Northwest Territory (Diamanti, 1998).

8. The Battle of Fallen Timbers (1794) near Maumee, Ohio and the subsequent Treaty of Greenville were key events leading to the cessation of hostilities between settlers and Native Americans in the upper Ohio Valley and opened the way for more extensive settlement. Other lower Ohio Valley communities were founded during the same era near the confluence of significant tributaries, including the Kentucky communities of Owensboro (late 1790s), Henderson (1797) and Paducah (1795). The second largest city on the lower Ohio for most of its history, Evansville, Indiana, was not founded until 1812. Another major event that opened the way for development of settlements in the lower Ohio Valley was William Henry Harrison's victory over the Shawnee at the Battle of Tippecanoe in Northern Indiana in 1811. The event was a turning point in British-inspired Indian problems since following that battle the confederation of the eastern tribes disintegrated.

9. The banks of the eastern Ohio River became the departure point for many settlers heading into the territory to the west. Flatboats were an important mode of transportation for settlers. The invention of the steamboat in the early 19th century also was highly significant in transforming the settlement of the entire Ohio Valley. Because steamboats were capable of two-way transportation of agricultural products and industrial supplies, they stimulated the economic growth of the region. Louisville became pivotal for the rapidly expanding trade between Pittsburgh and New Orleans, and all points in between, because the Falls of the Ohio remained an obstacle to navigation until a canal around the falls was completed in 1833.

10. Development of communities and trade during the early steamboat era transformed the Ohio Valley within a few decades. Consequently, by the middle of the 19th century, fine homes and public buildings were erected in communities all along the Ohio. Many 19th century buildings have been preserved in historic districts. Several of the finest surviving residences are on the list of National Historic Landmarks (NHL), which are considered to possess exceptional value or quality in illustrating or interpreting the heritage of the United States.

11. The 19th century also witnessed the construction of two suspension bridges over the Ohio that continue to be important as both historic and active transportation resources. The Wheeling Suspension bridge, begun in 1849, was the first bridge to cross the Ohio River, allowing the National Road (which became U.S. 40) to move forward. An even longer suspension bridge was completed between Covington, Kentucky, and Cincinnati in 1867. Now named the John A. Roebling Bridge, after its designer, the bridge became Roebling's prototype for the Brooklyn Bridge (1883).

12. Throughout the 19th century and during the Civil War, the Ohio River was an important geographic and cultural boundary between slavery and free labor. With its islands, fords and lower water level, the pre-impounded Ohio River offered opportunities for slaves to escape to freedom. Many places on both sides of the Ohio River served as stations on the Underground Railroad.

13. During the 20th century, high-lift dams constructed along its length transformed the Ohio River itself. The decades-long construction process will be completed when the most downstream project, Olmsted Lock and Dam (replacing Dams 52 and 53), is completed in 2011. By raising the level of the river, high-lift dams have inundated fords, portions of islands and mouths of tributaries that were above water during prehistoric and early historic times (USFWS, 2000). The older locks and dams on the Ohio River are of sufficient age to now be eligible for placement on the National Historic Register, thus representing a new generation of cultural resources along the Ohio River's ever-changing mainstem.

5.10.2 Current Conditions and Trends

1. The number of National Historic Landmarks (NHL) and listings on the National Register of Historic Places (NR) for counties along the Ohio River ranges from only one in a rural county of West Virginia to approximately 500 listings in the Louisville region, Jefferson County, Kentucky. Not surprisingly, the highest number of listings on the NR is associated with the most populous areas. Numbers of listings by county also reflect local and state levels of interest, effort, and funding for historic preservation.

2. The National Register also includes the historic districts previously mentioned. Such historic districts have been designated in both small communities and large cities along the Ohio River. The metropolitan counties associated with Pittsburgh, Cincinnati and Louisville have dozens of listed historic districts while the smaller cities of Steubenville, OH (Columbiana County), Wheeling, WV (Ohio County), Parkersburg, WV (Wood County), and Evansville, IN (Vanderburgh County) each have five to 10 historic districts. Other smaller communities and counties that have listed historic districts include Beaver, PA (Beaver County), Belmont County OH (near Wheeling WV), Sistersville, WV (Tyler County), Marietta, OH (Washington County). Huntington, WV (Cabell County), Aurora, IN (Dearborn County), New Albany, IN (Floyd County), Henderson County, KY (Henderson County), and Paducah, KY (McCracken County). Downtown Madison, IN (Jefferson County) is the largest historic district along the Ohio River, encompassing over 1,000 19th century structures.

3. Section 110 of the National Historic Preservation Act requires federal agencies, including the Corps of Engineers, to assume responsibility for preservation of historic properties owned or controlled by them and to locate, inventory, and nominate all properties that qualify for the National Register. Consequently, many of the locks, dams, buildings and equipment originally built by the Corps of Engineers on the Ohio mainstem are themselves considered to be cultural resources. During 1999, the Corps evaluated 70 sites associated with the navigational system along the Ohio River in accordance with National Register criteria related to age of structures, historical importance, and site integrity These sites represent the 51 lock and dams constructed in the first part of the 20th century as well as the 19 replacement "high-lift" lock and dams.

4. To complement this inventory, the Corps evaluated the engineering associated with the lock and dam construction in the Ohio River Context Study (McVarnish 2001). This study described the Ohio River navigation system as a "living laboratory of 20th

century lock and dam technology and concluded that it clearly meets the National Register's Criterion C, which states that structures that embody the distinctive characteristics of a type, period or method of construction are eligible. Because of its extensiveness and complexity, the Ohio River Navigation System pioneered the evolution of several significant areas of engineering, including lock filling and emptying technology; cofferdam technology and; power generation in navigation complexes in the United States.

5.11 SUMMARY OF AFFECTED ENVIRONMENT DISCUSSION

1. The environment affected by the Ohio River navigation system and all other actions – past, present, and future – consists of resources, ecosystems, and human communities collectively referred to as Valued Environmental Components or VECs. Ten VECS were examined during this study, but six received greater emphasis: 1) water and sediment quality, 2) fish, 3) mussels, 4) riparian and floodplain resources, 5) health and safety, and 6) river-based recreation. The four VECS receiving lesser emphasis were 1) air quality, 2) transportation and traffic, 3) socioeconomics, and 4) cultural resources.

2. The thorough examination of the VECs was bounded by both time and space. Temporal boundaries for the study were generally the years 1920 through 2060. However, historical data and anecdotes preceding this time frame were evaluated and included, when appropriate, to provide a comprehensive perspective. The spatial area for ORMSS was defined as the mainstem of the Ohio River and associated 100-year floodplain from Pittsburgh, PA, to Cairo, IL – a distance of 981 river miles (RM). In actual fact, impact areas varied as resource conditions and, in some cases, available data dictated.

3. This brief summary considers the 10 VECs in the sequence as presented in the first paragraph above. However, to gain an accurate understanding of the affected environment, it is important to bear in mind that VECs do not exist in isolation, but are integrated with each other. Recognizing this, the overarching goal of ORMSS has been to provide a holistic assessment of the Ohio River.

5.11.1 The Six Major VECS

1. **Water quality** of the Ohio River has been directly affected by socioeconomic factors and land use, including industrial development and agricultural activities along the river. In turn, water quality has profoundly affected the river's biological resources and recreation. The late 1800s through mid-20th century witnessed a marked degradation of water quality that began to reverse with the establishment of ORSANCO, the implementation of the Clean Water Act and other landmark environmental legislation, and an array of programs and educational efforts that continue into the present. Regarding the river's attainment of designated permissible uses, in 2003, 80% of the river's miles fully supported aquatic life use and 97% of the river's miles fully supported public water supply use. Contact recreational levels are still impaired, attaining fully supported use on 27% of river miles, primarily due to wet weather impacts of combined sewer overflows and nonpoint source pollution. Site-targeted efforts to reduce bacterial pollution from CSOs are needed along with special surveys for legacy-contaminated sediments

2. The decline in **native fish species** numbers and abundances and increase in pollution-tolerant species that occurred through the mid-20th century reflected both adverse water quality conditions and physical changes that occurred as the river was transformed from a free-flowing river to a series of deeper, slower pools created first by wicket dams, then by the present generation of high-lift dams. Declines of fish resources were most severe in the more populous, industrialized upper and middle sections of the river. Fish populations began to recover concomitant with improved water quality such that all portions of the river now support active sports fisheries. Other positive signs for understanding and improving the fish resource include development of the Ohio River Fish Index (ORFIn), and recent research suggesting that dams may inhibit fish passage less than previously thought and that many fish species will use the lock chambers to move between pools. Fish passage research strongly suggests, however, that fish passage through the dams becomes more prohibitive as fish move up the river. There is a highly migratory fish assemblage, often referred to as the Great River Fishes, which has not recovered in much of the river. This group includes species such as skipjack herring, blue suckers, sturgeon species and paddlefish. Since it is uncertain whether the Great River Fishes use the lock chambers to move between pools, but are thought to move through gate openings of the dams to migrate, this assemblage may be disproportionately affected, especially in the upper river. Possibly negative and largely unknown impacts on Ohio River fishes include the recent invasion of Asian carp species, moving upstream from the Mississippi River and continuing threats to native mussels, an important food source for fish.

3. The existing condition of **mussels** of the Ohio River is perceived as so precarious that many activities in and along the river present concerns to their future sustainability. Presently, five Ohio River mussel species are listed as federally endangered and many more species merit special concern both federally and by states bordering the river. In addition to habitat changes caused by high-lift dams, dredging and siltation, and nonpoint pollution, native mussels have been impaired by invasive zebra mussels, inadvertently introduced during the 1990s, and also may be measurably impacted by Asian carp in the future. The ability of the native fishes to serve as the mussel host species, particularly the Great River Fishes, and for those host species to move between pools during the reproductive life stage of the mussel is also a significant issue. Further studies on the population dynamics of these invasive species are needed to ascertain impacts on native mussels. On the plus side is substantial interest and progress in mussel research, including studies related to habitat restoration and mussel propagation.

4. The lack of awareness of environmental services performed by **riparian/floodplain resources (RFR)**, coupled with ongoing floodplain development, especially in the upper and middle river, led to the loss and fragmentation of these valuable commodities along the Ohio mainstem before such resources could be well-documented. However, recent decades have documented an increasing awareness of riparian services, including now regulated wetlands. Establishment of the Ohio River Islands National Wildlife Refuge has focused attention on the disappearance of islands, another unique riparian habitat type. Growing awareness of environmental services performed by RFR, as well as increasing demand for river corridor enhancement and protection may help move RFR toward a more sustainable future. Much will depend upon the establishment and success of environmental regulations and institutional programs, including incentives on privately-owned land.

5. Prior to 1920 and continuing into the 1960-70s, **health and safety** issues on the Ohio River represented a broad spectrum of risk factors related to workplace conditions, spills and discharges from commercial navigation, river oriented industries, and untreated municipal effluent. Little information was available to advise the public of these health and safety concerns. Reduced risks related to these factors have made the Ohio River a safer place to work, live, and play. However, problems associated with exceedances of biological standards, certain contaminants associated with fish consumption, and mixed signals regarding fish consumption standards persist. Possible growth of commercial navigation, water recreation, industries, and other river uses represent continuing challenges. Important efforts required for continued improvement, such as rehabilitation of sanitary sewer systems or reduction of mercury emissions from coal combustion, will require significant long-term investments to achieve results.

6. Prior to 1920, and continuing up to about 1950, the popularity of **recreation** on the Ohio River declined in concert with a degrading environment due to largely untreated and uncontrolled pollution discharges from growing municipalities, mining activity, and various types of industries and land uses along the river. During the past several decades, water quality improvements, combined with increased economic prosperity, have increased the demand for and stimulated the development of marinas, ramps and other recreation facilities along the river that support fishing and boating. Recently, more integrated riverfront planning also has addressed land-based recreation needs along the river and has increased opportunities for an expanded spectrum of recreational choices. A recreation study conducted for ORMSS indicated that although the perception exists that increased participation could lead to overcrowding and competition for limited resources, that perception does not currently seem to be an overriding influence affecting people's decisions to participate in river-related activities.

5.11.2 Additional VECs

1. During the period of rapid population and industrial growth continuing into the 1970s, **air quality** in the Ohio River Valley was in a progressively degrading state due to largely untreated and uncontrolled point and nonpoint pollutant discharges from coal fired power plants, other types of industries, and vehicular sources. Since implementation of the Federal Clean Air Act of 1970 and subsequent amendments, the air quality in the region has shown a steady improvement. Future improvements to air quality will depend on effective air quality monitoring and management efforts, including efforts to establish effective limits for mercury and to continue analysis of the need to control other types of emissions.

2. River-based **transportation and traffic** from 1950 to the present have often been characterized by problems related to construction of new infrastructure, demands that exceeded system capacities at numerous locations, and the use of auxiliary locks during repair and maintenance periods. Because of the navigation system's aging infrastructure, further problems are anticipated unless investments occur. An important future question relates to the effect potentially marked increases in recreational boating may have on Ohio River navigation system operations.

3. After a past characterized by rapid conversion of natural resources and landscapes to meet the industrial and infrastructure demands of a rapidly expanding population and

related volatile patterns of explosive growth and recession cycles, **socioeconomic resources** in the Ohio valley are currently well-developed and stable. In recent decades, improved water quality has enhanced redevelopment interest for many riverfront neighborhoods. Projected slower growth patterns in the future may present opportunities to proceed with gradual and better planned processes of development and redevelopment serving the needs and interests of a stable and established population.

4. The **cultural resources** of the Ohio Valley are rich and varied, including prehistoric sites, historic homes and districts, and sites associated with significant events in American history. Despite the large number of cultural resources, many sites remain unsurveyed. Implementation of cultural resources legislation, including creation of the National Register of Historic Places and establishment of State Historic Preservation Offices (SHPOs), has heightened awareness of the need to preserve cultural resources along the Ohio River. Because of their engineering innovations and age, many components of the Ohio River navigation system are receiving consideration as historic cultural resources.

SECTION 6
OHIO RIVER PROBLEMS, NEEDS AND OPPORTUNITIES

This section begins with a description of the navigation and ecosystem sustainability problems and needs that exist, or that are expected to exist in the future, along the Ohio River mainstem. These problems and needs provide an opportunity to improve the balance of economic and environmental benefits of the system. Various measures to alleviate these problems and address needs are identified and examined. They include both nonstructural and structural measures for navigation, some of which have proven effective in the past and others that are considered to have the potential to address existing and future problems and needs. Also included are descriptions of problems, needs, and opportunities for improving ecosystem sustainability in and along the Ohio River. This section includes the identification of Planning Objectives and the associated planning assumptions and constraints that frame the formulation and evaluation of alternative measures for both navigation and ecosystem sustainability improvements in subsequent sections. This section addresses the first step of the plan formulation process (Section 2.4.1).

6.1 BACKGROUND

1. The Ohio River provides a significant link to the nations' transportation network while at the same time supporting valuable natural resources that should be sustained for future generations. This study strives to balance economic and ecosystem needs of the Ohio River for the overall benefit of the nation for the next 60 years.

2. Economic efficiency is the ability to perform a task in a timely and cost-effective manner. The efficiency of the Ohio River navigation system is measured in terms of the time and cost it takes a vessel to move between points on the river and the cost to operate and maintain the system. Inefficient lock operations are characterized by unnecessarily high delays and can result from insufficient capacity due to a chamber's physical dimensions or unreliability of the physical components.

3. A lock's capacity is largely determined by factors including lock chambers' dimensions; approach conditions, the percentage of empty barges, empty and fill times, and lock availability. Of these, chamber dimensions and lock availability are the most important. Larger chambers can process larger tows in single operations, or "cuts", leading to a greater throughput "capacity", typically measured in tons that could be moved through a project in any given year. Availability refers to the total time that a chamber is "open for business", including those times during a lockage or when sitting idle, or at all times except when the chamber is not available to lock vessels, or "closed". Availability is strongly influenced by lock component reliability (less reliable locks require more downtime for repairs, thereby decreasing availability).

4. Ecosystem benefits are not measured in dollars due to the non-monetary nature of environmental outputs. Rather, ecosystem benefits are more appropriately measured by changes in the ability of systems to function in a self-sustaining, natural manner. Ecosystem sustainability (ES) is determined by assessing the ability of the most sensitive resources to continue to function in a natural self perpetuating manner. As such, indicators of environmental sustainability are measured in terms of technically valid scientific measurements, regulatory thresholds or regulatory protection policies, and composite indices of ecological health. These indicators are specific to each type of resource being evaluated. Examples include measurement of water quality parameters (scientific), compliance with stream use designations (regulatory thresholds), and indices of biotic community health (composite). This study considers the overall results of indicators for each resource category and evaluates the historic, current, and future sustainability of that resource under both the Without-Project and With-Project conditions.

6.1.1 Chamber Dimension Considerations

1. All Ohio River facilities are currently operating with two lock chambers, a main chamber to lock most tows and an auxiliary (usually smaller) chamber available to process recreation vessels or small tows that can lock through in one lockage operation (or "cut") and to process all tows during closures of the main chamber.

2. At all Ohio River projects except the upper three, Emsworth, Dashields and Montgomery (EDM), the main chambers are large enough to process 1200' tows with a single passage. This length was determined in studies for the high lift system to handle the largest barge tows operating efficiently on the Ohio River and adopted for the main lock at each new project. Tows larger than this length sometimes transit the lower river and are forced to reconfigure to transit through the 1200' chambers in a single passage. However, the towing industry has adapted its typical Ohio River barge configuration to accommodate the 1200' chambers. The main chambers at Ohio River facilities typically processes over 90 percent of the commercial tonnage at times when both chambers are available to process tows, reflecting the fact that most tows (barges + tow boat) are larger than the auxiliary locks and are processed much quicker through the main chamber. Processing tows through a chamber smaller than the tow size requires multiple passages, which significantly increases the time to process the tow. The small size of an auxiliary chamber becomes critical when that chamber must be used to service all traffic when the associated main chamber is closed. During these times, lines of tows waiting their turn to lock through form in upstream and downstream approach areas. As the size of the auxiliary chamber at most Ohio River projects, as well as the main chamber at the upper three projects, is smaller than the maximum size tow, their adequacy through the planning horizon is a major emphasis of this study.

6.1.2 Lock Service Availability

1. Locks may be rendered inoperable due to a variety of reasons, including the following categories recorded in the Corps Lock Performance Monitoring System: collision/accident, debris, flood, fog, hardware malfunction, ice, vessel interference, other, rain, river current/out draft, snow, testing and maintenance tow detained by Corps or Coast Guard, tow malfunction or breakdown, tow staff elsewhere occupied, and wind. Many types of interruptions are beyond the control of the Corps, such as fog and other weather-related events[1]. However, closures due to maintenance of lock components typically produce the greatest disruption to service because they are typically the longest in duration.

2. A system of infrastructure as large as the Ohio River system of locks and dams requires frequent maintenance, ranging from small adjustments and repairs to major component replacements. Maintenance actions can be proactive – repair a component before it becomes inoperable (preventative maintenance), or reactive – repair or replacement after a component fails. It is also necessary to take lock chambers out of service and dewater locks at scheduled intervals to allow for inspection and/or to perform repairs or replacements of lock components such as filling and emptying valves and lock gate components. The goal of preventive maintenance is to avoid component failures and the need for lengthy unscheduled repairs. Unscheduled repairs that require closure of a main chamber can be very costly as repairs would be completed under emergency conditions and industry would not be able to prepare for the unanticipated impacts to their operations. There is a trade-off as preventative maintenance increases the up-front costs to operate and maintain a lock, but the payoff is a reduction overall repair costs and navigation delays.

3. Lock and/or dam maintenance, whether minor maintenance (over a few days) or more extensive work lasting several weeks or months to replace major components of the lock chamber, often requires work vessels and procedures that interfere with and delays the passage of vessels through the navigation system. The repair of some components, including concrete lock walls and miter gates, require chamber dewaterings that are not only costly in and of themselves, but incur additional and sometimes much higher costs to industry in the form of added delays when the main chambers must be closed for extended periods and all traffic forced to lock through the smaller auxiliary chamber of any facility. This is particularly critical at locks where the traffic levels exceed the capacity of the auxiliary chamber.

4. As any structure ages, the natural deterioration process dictates that maintenance requirements increase, resulting in more frequent and costly repairs and replacements. In other words, locks become more unreliable with age. Attendant with maintaining an increasingly unreliable lock is more frequent and longer closures of the main chamber. In addition to the costs to complete the work, significant costs in the form of added delays to

[1] The Pittsburgh District Corps of Engineers is partnering with the Port of Pittsburgh Commission on their "SmartLock" project by making lock facilities available at Emsworth, Dashields and Montgomery Locks on the Ohio River for installation of recently developed state-of-the-art navigation technology to assist safe navigation of the lock in low visibility conditions of darkness, fog, rain, and snow. For more info, see the Commission's web page http://www.port.pittsburgh.pa.us/home/index.asp?page=12

the commercial towing industry are incurred during closures of the main chambers at any project. This has begun to occur on a more frequent basis for Ohio River lock chambers.

6.1.3 Structural Concerns and Reliability Issues

1. Reliability can be loosely defined as a measure of safety or assurance of adequate performance of a structural component. Structural strength properties may also be a function of time, usually in degrading fashion. Structural integrity is adversely impacted by factors including structural deterioration of members due to factors including corrosion and fatigue.

2. The age of a structure is not the only factor in the deterioration process, but the older a structure is the more operating cycles is has undergone, thus, fatigue also is an important determinant with corrosion in the reliability of the lock components such as miter gates, culvert valves, and operating machinery. Increasing age of any lock or dam component usually correlates to increasing levels of deterioration, depending upon prior maintenance levels and repair work. Other factors that impact component reliability include the level of preventative maintenance and repairs and the original design parameters incorporated into the original construction. It is necessary to repair or replace some of these major components at various points throughout the life of any project.

3. When lock and dam facilities deteriorate significantly and/or where opportunities arise to increase operational efficiency, Major Rehabilitation (MR) of the facility is usually considered. By regulation, a MR project:

- requires approval by the Secretary of the Army and construction **is** funded out of the Construction General (CG) Civil Works appropriation for the Corps of Engineers;
- requires a minimum of two Fiscal Years to complete;
- costs over $10.6 million in capital outlays **for inland navigation projects** (in Fiscal Year 2006) for reliability improvement projects or over $1.30 million in capital outlays (in Fiscal Year 2005) for efficiency improvement projects. These thresholds are adjusted annually by regulation; and
- reliability and efficiency improvement projects require, for inland locks, **construction is** 50/50 cost shar**ed** with the Inland Waterways Users Trust Fund (whereas other maintenance is 100% Federally funded from the Operations and Maintenance account).

4. The Corps' experience at Ohio River navigation projects has been that major lock and dam components become a reliability concern when those components are from 40-70 years old (reflecting the "50-year" design life typically ascribed to projects). The aging lock and dam infrastructure is a critical concern since one-third of the lock chambers (excluding L/D 52 and 53) will be beyond their design life as of 2010, the beginning of the study analysis period (based on years chambers became operational shown in **Table 4-2**). Furthermore, nearly all will surpass this design life early in the analysis period. When the reliability of components at a site degrades to the point that replacement is justified, the economics and practicality of "bundling" of multiple components together into a single

major rehabilitation project is considered if it meets the MR threshold requirements. Such projects can save considerable time and money when compared to individual lock component replacements at different times.

6.1.4 Ecosystem Considerations

1. Insufficient lock capacity and unreliable lock performance impose delays to traffic. These delays not only increase economic costs to shippers and the towing industry, but the additional time spent by tows in queue on the river, particularly around the locks, creates negative impacts on the ecosystem as well. This report considers different measures to more efficiently accommodate future traffic demand in an environmentally sustainable manner, both in the vicinity of the locks and along the entire length of the pools. To aid in this effort, cumulative environmental effects are considered in assessing modernization needs in accordance with the Corps' Environmental Operating Principles (EOPs). Key concepts of the EOP Doctrine include:

- Illuminate the ways in which the U.S. Army Corps of Engineers missions must be integrated with natural resource laws, values, and sound environmental practices.
- People everywhere will recognize the Corps roles in, and responsibilities for, sustainable use, stewardship, and restoration of our Nation's natural resources.
- Make evident the connection among water resources, protection of environmental health, and the security of our Nation.
- We can chose to design and act either in conflict with nature or in ways that take inspiration from nature and are modeled after it.

2. While the EOPs were released after the ORMSS was well underway, the Product Delivery Team conducted a review of ORMSS in light of these principles to determine if adjustments were needed to more fully align the study with the principles. This review found that the specific connections between the EOPs and ORMSS are as follows:

Principle 1 - Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse and sustainable condition is necessary to support life.

ORMSS – Achieving environmental sustainability is an overarching component of the ORMSS. This study assessed impacts in terms of how each operation, maintenance, or construction measure evaluated in this study affected long-term self-sustainability of the resource base. Any alternative (comprised of a set of measures) that would move a resource toward an unsustainable condition would result in a determination of significant adverse impact. This would require development of a mitigation program that would avoid, minimize, and compensate impacts to restore a desirable level of sustainability. Following release of the EOPs and consideration of their implications for the ORMSS, the study team developed alternatives that incorporated measures needed to improve long-term sustainability of aquatic and terrestrial ecological resources. Implementation of these would constitute a significant beneficial impact and would help to establish and maintain a balance of economic and environmental sustainability.

Principle 2 - Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of Corps programs and act accordingly in all appropriate circumstances.

ORMSS - Interdependence of life and physical environment was engrained in the assessment of environmental impacts of the ORMSS. The resource categories termed Valued Environmental Components (VECs) considered in the Cumulative Effects Assessment (CEA) for the ORMSS included human resources and conditions as well as ecological resources and habitats. Also, NEPA requires consideration of impacts to the human environment which includes human dimensions as well as natural resources. For all VECs the assessment examined how possible changes to characteristics of the physical environment affected the living resources dependent upon those environments. Further, the development of ecosystem sustainability improvement measures reflects the linkage between promoting a quality environment and the quality of life.

Principle 3 - Seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another.

ORMSS - Balance and synergy among human development activities and natural systems was a cornerstone of the ORMSS through pursuit of both an efficient navigation system and a more sustainable environment. The study sought to incorporate environmental design measures into alternatives to first avoid or minimize adverse impacts while providing for an efficient navigation system into the future. The ORMSS also resulted in establishment of an authorized program in 2000 to restore ecosystems degraded by previous human activities. Unfortunately, the program has not received Congressional appropriations for implementation to date and is now a candidate for de-authorization. The ORMSS developed alternatives to further improve the long-term sustainability of aquatic and terrestrial ecosystems in order to achieve both economic and environmental benefits. To enable follow through on both economic and environmental objectives, a "monitoring and adaptive management" strategy (stewardship program) is recommended as an on-going activity following completion of the current study. This approach would allow the Corps to monitor selected indicators of navigation system performance and environmental sustainability (i.e., keep a finger on the pulse) and to determine and implement adjustments or corrective actions in order to continue on a path toward improved and balanced sustainability.

Principle 4 - Continue to accept corporate responsibility and accountability under the law for activities and decisions under our control that impact human health and welfare and the continued viability of natural systems.

ORMSS - ORMSS not only took a very conscientious approach to compliance with environmental laws and regulations, but went beyond those requirements. For example, though not required by regulation, the study team decided to integrate the SIP/PEIS as a single report. The Corps' commitment to preparing a comprehensive CEA of all past, present, and reasonably foreseeable actions affecting each resource is further evidence of the commitment to comply with both the spirit and intent of environmental laws. Throughout the study process, environmental considerations were on equal footing with

engineering and economics. The extensive communications, outreach, and public/agency inclusion through the Interagency Working Group (IWG) helped ensure accountability, full disclosure, acceptability, and credibility of environmental considerations prior to recommending or making decisions.

Principle 5 - Seeks ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.

ORMSS – The CEA is the center piece of fully integrating the National Environmental Policy Act into the ORMSS. The study considers the full life cycle of navigation improvements as well as environmental life cycles. Identification of needs for both navigation and ecosystem sustainability ensures long-term economic and environmental sustainability. In performing the CEA, stressors affecting various resources were examined to determine resiliency of each resource and its capacity to withstand further stresses before new activities are implemented. In addition, high priority needs of ecological resources were determined to identify actions that could be taken by the Corps and by others to improve conditions of those resources.

Principle 6 - Build and share an integrated scientific, economic, and social knowledge base that supports a greater understanding of the environment and impacts of our work.

ORMSS - A substantial knowledge base was established during the ORMSS. Examples include mapping of substrate conditions, depths, structure, vegetation, and hydrologic conditions for the entire 981 mile length of the Ohio River for use in a predictive model that evaluates effects of tow movements on aquatic habitats. These and several other types of information that have been developed through the study will prove extremely valuable to many researchers, natural resource managers, students, and decision-makers well into the future. The fish movement studies that have been conducted help answer many questions about how and when fish move from pool to pool on the river and how to manage fish movements to improve connectivity among pools. Compilation of information on past, present and future resource conditions provides a context for researchers and managers to design studies and formulate management actions. Another example of this principle includes compilation of a pool by pool mussel database.

Principle 7 - Respect the views of individuals and groups interested in Corps activities, listen to them actively, and learn from their perspective in the search to find innovative win-win solutions to the nation's problems that also protect and enhance the environment.

ORMSS - Since the beginning of the ORMSS, the IWG has existed to identify issues and concerns that needed to be addressed in the study process and to provide input to the overall scope of the effort. In addition, this group was used to identify data sources and data needs, as well as to design studies and actively participate in assessment of impacts. The group initially was comprised of state and federal agency personnel, but later expanded to include NGOs. In addition to the interagency group, there have two series of scoping meetings along the length of the river, numerous mailings, newspaper articles and press releases, brochures, and other proactive efforts to seek input to the study process. Further, another series of public meetings was held during the public review period on the draft report to solicit the views of the public at large on the findings and recommendations

in the report. Also, an extensive Communications Plan was developed for the study and the SIP/PEIS has a Communications Appendix to accompany the Engineering, Economics, and Environmental appendices. To communicate ORMSS activities, processes, and findings in a broad context, study participants have delivered presentations to numerous audiences and have written articles for publication in peer reviewed journals (see Communications Appendix).

6.2 PLANNING OBJECTIVES

1. Now that the problems and needs to be addressed in this report have been introduced, and several alternative solutions have been discussed, a word is in order about planning objectives. Objectives are defined as those criteria by which one alternative plan is weighed against another. The alternative or alternatives which best meet those objectives, after careful economic, environmental, institutional, and social-impact analyses would be the preferred plan(s).

2. Based on the concerns identified above, three planning objectives are specified for Ohio River Mainstem System Study:

Ensuring Future Navigability – providing appropriate maintenance to existing navigation facilities (lock, dams, and channel improvements) and providing new, improved, or replacement facilities (as justified) to ensure continued and reliable navigation for nine-foot draft vessels throughout the length of the Ohio River.

Improving Navigation Efficiency – exploring various options to schedule and execute maintenance as well as structural options so as to maximize National Economic Development (NED) net benefits – for example, by identifying cost-efficient measures to reduce transportation shipment costs.

Enhancing Environmental Sustainability - identifying means within the authorities of the Corps of Engineers (or other agencies) to minimize degradation of environmental resources which might be caused by transportation or other development, and to improve sustainability of resources in and along the Ohio River. The Corps of Engineers Environmental Operating Principles define environmental sustainability as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations."

6.3 OHIO RIVER PROBLEMS AND OPPORTUNITIES RELATED TO NAVIGABILITY AND NAVIGATIONAL EFFICIENCY

1. There are two general areas of concern and one opportunity area addressed in this SIP Report for Ohio River Navigation Projects:

(1) Insufficient capacity of small chambers (less than 1200' long),
(2) Lock and dam condition and reliability, and
(3) Opportunity for operational efficiencies

2. The primary concerns for the future navigation on the Ohio River mainstem are times when all traffic is forced through the smaller auxiliary lock at any project with a small auxiliary chamber. Deteriorating lock conditions through time will increase the need to close the larger locks and magnify the importance of auxiliary chambers to the overall efficiency of the ORS. Operational measures to reduce congestion could help alleviate these conditions. These problems and opportunities are described in detail below.

6.3.1 Small Chambers

6.3.1.1 Small Auxiliary Chambers

1. Only three Ohio River projects have two 1200' chambers, large enough to accommodate the maximum size tow, Smithland, McAlpine, and Olmsted. The other 14 Ohio River locks and dams below Montgomery, including the R.C.Byrd L&D that was modernized in 1993, have a 1200' long main chamber but a shorter (600' long) auxiliary chamber. At those sites during main chamber closures, the large majority of tows (which are longer than 600'[15]) must break apart and process in two pieces – a double-cut lockage. Double cutting of tows reduces vessel throughput by as much as 50-75 percent, and long vessel waiting-lines (queues) upstream and downstream of the locks develop. Delay costs incurred by commercial shippers can reach into the millions of dollars, depending upon the site, closure duration, time of year, etc. As a consequence of the need for double-cuts through the auxiliary chambers, the capacities of those chambers are considerably lower than the main chambers at the 14 projects (see **Table 6-1**).

2. The three uppermost locks near Pittsburgh - Emsworth, Dashields, and Montgomery (EDM), each have a main chamber measuring only 110' x 600' and an auxiliary lock measuring 56' x 360'. They are the lowest capacity locks on the Ohio River (see **Table 6-1**). The impacts due to main chamber closures at these projects are magnified as all traffic must use the very small 56'x360' chambers. These small chambers can only process one barge at a time. Further, there is a five-cut limit at these three projects during closures of the main chamber. Therefore, larger tows that would require a double lockage through the main chamber require processing in several tows through the auxiliary. A double lockage through the main chamber at these projects normally takes 3 hours, which processes 15 barges. A five cut lockage through the auxiliary chamber takes 4 to 5 hours and can only process up to 5 barges.

3. The impacts of main chamber closures can be seen by considering the data in **Tables 6-2 and 6-3**. The average annual delays in **Table 6-2** are below 40-50 minutes at all new projects for most years. Years of high delays from **Table 6-2** correspond in most

[10]Between 71% - 93% of all traffic locking through any of these 17 sites during 1998-2002 were longer than 600'.

cases to years of main chambers closures noted in **Table 6-3**. For example, in 1994, the Emsworth main chamber was closed during the entire month of November for maintenance. The average delay during that closure for all tows processed was over 26 hours per tow, and individual delays reached as high as 3 days. The average delay during that closure event was roughly about 25 times the typical average delay at Emsworth of 45 minutes or so in years without a main chamber closure. This average delay translated into the increased average delay for the entire year when compared to other years with no main chamber closure. The dramatic reduction of delays at Byrd (formerly Gallipolis) reflects the replacement of the old 110'x600' and 110'x360' chambers with 110'x1200' and 110'x600' locks in 1993.

TABLE 6-1
Ohio River Mainstem Locks
Age, Chamber Dimension and Capacity, 2004 Tonnage
(Million Tons)

Lock		Chamber Dimension		Chamber Capacity			2004
Project	Age	Main	Auxiliary	Main	Auxiliary	Both	Tonnage
Emsworth	84	600x110	360x56	39.4	12.6	45.8	18.8
Dashields	76	600x110	360x56	46.5	12.9	51.7	19.7
Montgomery	69	600x110	360x56	43.9	12.9	47.6	20.3
New Cumberland	46	1200x110	600x110	78.5	44.5	132.9	31.5
Pike Island	40	1200x110	600x110	99.5	47.9	151.2	38.9
Hannibal	33	1200x110	600x110	103.1	52.4	152.1	50.1
Willow Island	33	1200x110	600x110	107.5	54.2	155.1	48.1
Belleville	37	1200x110	600x110	114.6	56.3	167.2	51.4
Racine	38	1200x110	600x110	110.5	54.0	151.1	52.3
R.C. Byrd	12	1200x110	600x110	116.3	55.5	151.0	57.8
Greenup	46	1200x110	600x110	113.3	54.3	144.2	64.5
Meldahl	43	1200x110	600x110	116.3	55.5	151.0	55.3
Markland	46	1200x110	600x110	119.0	57.1	160.5	50.1
McAlpine	44	1200x110	1200x110	120.0	123.0	225.5	52.8
Cannelton	34	1200x110	600x110	124.0	59.0	162.1	56.9
Newburgh	30	1200x110	600x110	135.6	61.7	169.8	67.2
J.T. Myers	30	1200x110	600x110	137.3	63.6	170.6	67.9
Smithland	26	1200x110	1200x110	143.4	132.9	264.4	77.0
Olmsted[1/]	0	1200x110	1200x110	na	na	na	95.0

1/ Currently under construction, 2004 tonnage is for L/D 52.

Table 6-2
Historic Average Lock Delays at Ohio River Projects
(Minutes/Tow)

Project	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Emsworth	33	45	40	180	56	48	63	57	51	40	86	39	52
Dashields	30	32	32	38	30	44	140	37	35	32	53	38	37
Montgomery	40	62	73	73	42	61	50	55	57	57	46	178	33
New Cumber	11	11	13	19	16	15	14	20	15	15	17	74	19
Pike Isl	11	11	14	18	14	15	51	15	15	66	18	23	22
Hannibal	12	13	14	18	14	15	51	15	16	15	21	19	24
Willow Isl	11	12	14	21	17	20	17	21	43	25	25	62	25
Belleville	10	12	13	14	67	30	24	19	21	21	20	21	22
Racine	15	15	68	32	25	24	23	29	24	27	32	30	30
Gallipolis	254	197	---	---	---	---	---	---	---	---	---	---	---
R.C.Byrd (1)	---	---	55	59	35	40	34	38	37	40	35	25	34
Greenup	299	36	41	97	45	45	53	142	140	56	55	46	342
Meldahl	48	43	44	45	38	36	48	50	56	59	95	199	58
Markland	29	31	37	174	46	49	33	35	59	36	58	52	73
McAlpine	62	55	179	68	56	53	437	59	150	87	84	62	51
Cannelton	53	47	53	76	38	40	38	36	86	40	45	40	35
Newburgh	60	26	30	28	23	45	23	24	27	28	47	40	35
J.T. Myers (2)	45	44	45	63	64	44	40	43	40	66	184	32	39
Smithland	9	19	19	18	17	8	9	14	4	2	4	43	68
L/D 52 (3)	186	90	9	152	126	74	134	146	242	183	170	184	29

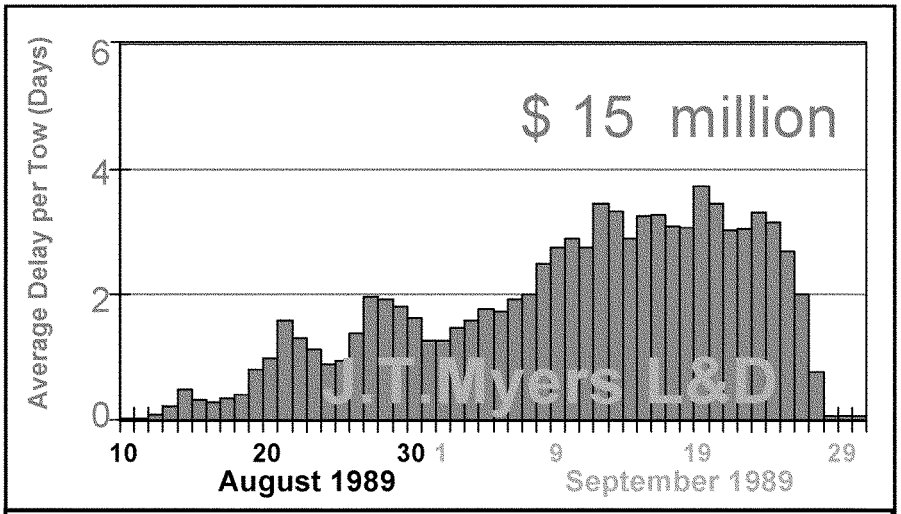
Source: Corps of Engineers Lock Performance Monitoring System Data
(1) In 1993, R.C. Byrd Locks replaced the smaller Gallipolis Locks.
(2) Uniontown L/D was renamed J.T. Myers L/D in 1997
(3) Averaged over all tows using the facility, including those using the navigable pass.

TABLE 6-3
Delays to Commercial Tows During
Recent Extended Ohio River Main Chamber Closures
(1991-2003)

Project	Days of Closure	Number of tows locked	Beginning Date of Closure	End Dates of Closure	Average Delay per Tow (hours)
Greenup	52		9/8/03	10/31/03	
Willow Island	31	367	10/15/02	11/15/02	7.3
Meldahl	42	555	6/17/02	7/28/02	23.3
Montgomery	26	231	6/18/02 & 7/14/02	6/25/02 & 7/31/02	31.4
New Cumberland	54	630	10/17/02	12/9/02	6.7
Myers	24	367	10/9/01	11/1/01	35.6
Emsworth	17	179	11/1/01&11/13/01	11/9/01&11/21/01	17.3
Pike Island	31	429	4/24/00	5/24/00	5.7
Greenup	29	390	11/2/99	11/30/99	21.8
Willow Island	38	420	6/21/99	7/28/99	4.0
Markland	10	119	6/19/99	6/28/99	10.9
McAlpine	16	155	9/13/99	9/28/99	36.5
Greenup	19	285	6/1/98	6/29/98	30.8
McAlpine	29	235	8/1/97	8/29/97	100.0
Markland	40	535	7/18/94	8/27/94	20.3
McAlpine	12	138	11/14/93	11/26/93	55.7
Greenup	32	470	6/10/91	7/12/91	30.9

4. An example of the economic impact of main chamber closure is shown for the 1989 event at Uniontown L/D (now J.T. Myers) in **Figure 6-1**. The average delay per tow waiting in queue reached 70 hours and the total economic impact surpassed $15 million (1999 dollars) of additional costs to commercial tows. These costs only reflect increased wait times spent in queue, and do not include other types of costs that shippers incur, such as diverting shipments to more expensive land based modes to avoid the increased travel time. **Table 6-2** shows that the average delay for Uniontown L/D (now J.T. Myers) that year were increased to over six hours per tow in 1989, eight to nine times greater than the typical delays for this facility. The Corps and industry take steps during main chamber closures to minimize the impacts (see Section 6.3.3); however the effectiveness of these measures is limited as reflected in the large delays that still develop.

FIGURE 6-1
Waiting Time at Myers During 45-Day Closure
Of Main Chamber in 1989



Plot of average waiting time (delay) per locked tow, during a 45-day maintenance event at the Main chamber of Myers L&D, 10 Aug.1989 -25 Sept.1989. All vessels were required to use the smaller Auxiliary chamber. Total cost of delays to commercial vessels was estimated at $15 million (1999$).

5. It is very important to note that the events shown in **Table 6-3** reflect scheduled closures (except McAlpine in 1993) in which industry was provided ample notice ahead of time and adjust operations to minimize the delays associated with those closures[3]. As infrastructure ages, unexpected and unscheduled closures become more frequent. The delays to navigation and the associated delay costs would be significantly increased if the closures were due to unexpected major failures and industry had no advance warning to make alternate plans. The 2003 Greenup Lock closure also involved unexpected emergency repairs. Originally, the lock was scheduled to be closed for an 18-day period for cyclic maintenance. However, during the course of an inspection process, some serious cracking in the lock gates was discovered, and the closure was extended to make the necessary repairs. This closure stretched to over 52 days. Costs to the navigation industry (shippers and carriers) were extensive based on a post-closure survey, estimated over $40 million even with partial information. In 2004 and 2005, damaged lock gates at McAlpine and Hannibal locks, respectively, required unscheduled repairs. Each of these events resulted in total river closure due to on-going construction of the auxiliary chamber at McAlpine and concurrent maintenance of the auxiliary chamber at Hannibal. The Corps took extraordinary steps in each of these events to minimize the duration of river closure. The McAlpine closure was completed and repairs completed in 10 ½ days rather than the

[3] Examples of the ways industry adjusts operations during main chamber closures include pre- and post-closure shipping to build and/or replenish stockpiles, shipping via other routings for all or part of the trip, making deliveries from alternative sources, and rearranging their shipping plans to minimize trips through the projects.

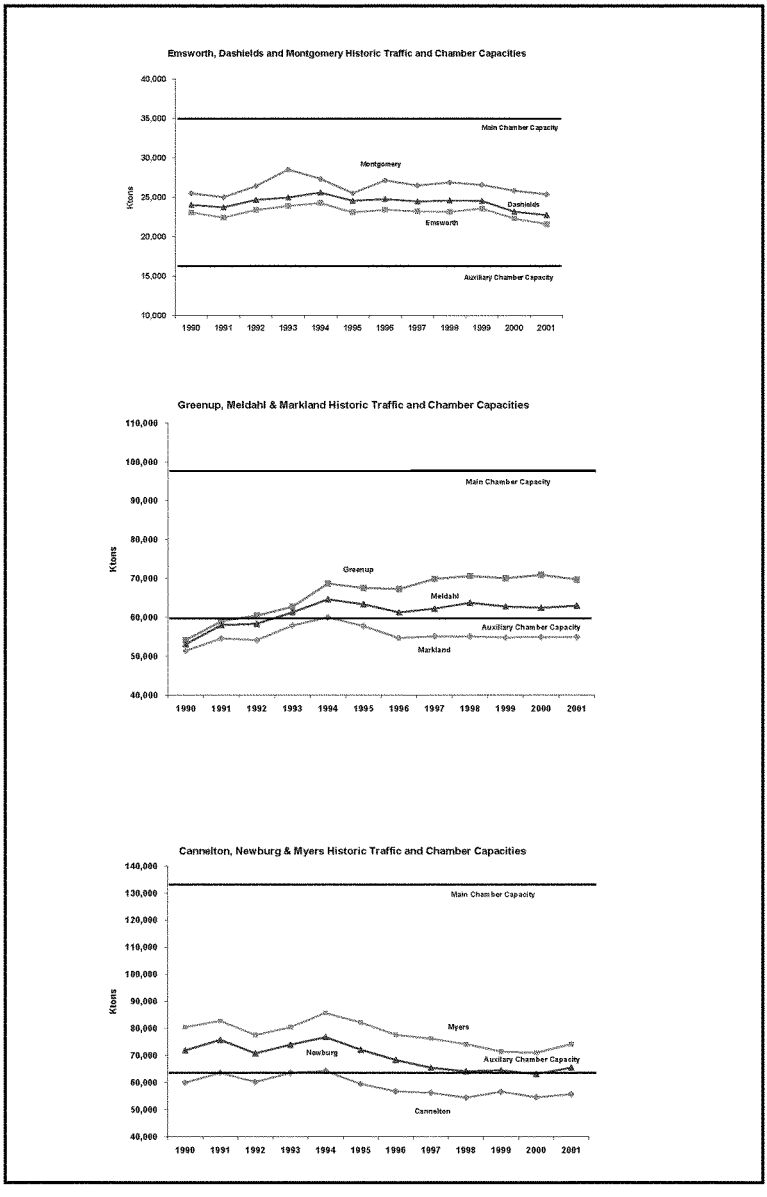
14 days estimated beforehand. However, each still resulted in added costs to industry over and above costs due only to scheduled maintenance.

6. The highest average delays per tow during main chamber closures are experienced at projects where the auxiliary capacities are less than the current traffic levels. This is generally the case since traffic arrivals during main chamber closures approximately equal the rate during typical normal operations, when both chambers are operating, and only lessen when delays become excessive (documented in the Traffic Management Report). Referring to **Figure 6-2**, the three upper Ohio River Locks and Dams are very susceptible to high average delays per tow due to the very small capacity of the auxiliary chamber at those projects. Similarly, the traffic levels at Myers and Greenup are in excess over the respective auxiliary chambers and that excess is greater than at the lower river projects. This explains in part why extensions of the auxiliary chambers to 1200' at Greenup and Myers locks and dams were advanced for project authorization in 2000. These extensions would allow traffic to be processed through a 1200' chamber at all times (unless both chambers are closed) and thereby greatly reduce delays. This study considers the need for larger auxiliary chambers at all facilities that do not have or are not authorized to have twin 1200'x110' lock chambers, or all facilities except Smithland, McAlpine, Olmsted, Greenup, and Myers Locks and Dams.

7. Environmental impacts of barge traffic also increase due to long queues of traffic. Waiting towboats scour the substrate and create suspension of sedim ents, thus negatively affecting water quality. As these towboats idle, there are increased emissions, degraded air quality, and wasted fuel. In the lower Ohio River, tows that "nose-in" to the shore for mooring damage shoreline vegetation, destroy shallow water habitat, degrade mussel beds, erode banks and debase aesthetic values. Increased noise levels can also be experienced.

8. Another aspect of these extended main chamber lock closures is the added number of operations required of tow personnel to accommodate the additional lockage requirements. Tows must be disassembled and reassembled during multiple lockages, which increases the risk of injuries to deck hands. There is increased risk to recreational boaters who must maneuver around tows in queue and possibly simultaneously lock with those tows.

FIGURE 6-2
Recent Ohio River Traffic Compared to Chamber Capacities at Several Ohio River Projects



6.3.1.2 Small Main Chambers at Emsworth, Dashields and Montgomery

Although not a problem at present, the small main chambers at EDM require that all tows greater than 600 feet double cut through those projects at all times. Significant numbers of tows greater than 600 feet long travel through these projects, resulting in additional delays to commercial traffic. From 1991 – 1999, over one-half of all tows processed through Montgomery in each year required two cuts. At Emsworth and Dashields, one-third to one-half of all traffic through the main chambers required two cuts. These chambers also present a bottleneck between the remainder of the Ohio River where the main chambers are 1200 foot-long and the Monongahela River with 720 foot-long chambers. Alleviating this bottleneck would be expected to result in some increase in river traffic as discussed in Section 9. This study will consider the benefits and costs of larger main chambers at EDM.

6.3.2 Lock and Dam Conditions

1. Ensuring future navigability of the existing lock and dam system requires reliable performance. As noted earlier, age is not the only factor in determining lock conditions, but it is telling to note the current ages of the Ohio River Locks and Dams from **Table 6-1**. Replacement of L&Ds 52 and 53 with the new Olmsted project and the new chamber being constructed at McAlpine L&Ds will improve the age situation somewhat, but the condition and the potential need to replace expensive lock components will be a significant concern throughout the 21st century. The ages of the existing Ohio River facilities in 2002 range from nine years at R.C.Byrd to 81 years at Emsworth. Many features at EDM were rehabilitated during the 1980s, yet the condition of concrete and possibly other components remain a significant concern. Just about all of the closure events described in Section 6.3.1.1 are a result of repairing or attending to main chamber components in poor condition.

2. This study evaluates the reliability of all major components, including mechanical equipment and concrete wall sections that are critical to lock operation. The most important lock components were modeled through state-of-the-art analytical engineering reliability methods. A formal two phase screening process was used to determine which components should be modeled using reliability techniques. For more information refer to the Engineering Appendix that details the screening and overall reliability modeling effort. The Engineering Appendix outlines the selection of the components for reliability modeling, as well as the detailed part of the analysis.

3. For all facilities the potential exists for movement (or stability) of individual wall sections, consisting of entire monoliths[4] of a wall, either by sliding or rotating into the chamber. The analysis is covered in the Engineering Appendix in detail, but due to original design safety factors and the load cases examined lock wall stability was a reliability issue only at the EDM facilities.

[4] All lock walls are constructed in individual monolith sections to accommodate joints that allow for expansion and contraction of material, as opposed to one continuous section.

4. The additional concerns at Emsworth, Dashields, and Montgomery involve internal cracks throughout the concrete monoliths that could eventually propagate through entire wall sections and lead to significant movements of monolith sections. A diagram showing failure potential failure scenarios is shown in **Figure 6-3**. A major cause is concrete deterioration. The main cause of concrete deterioration at locks and dams is weathering and freeze-thaw action. Since these three locks and dams were constructed prior to 1950, before the advent of air-entrainment in concrete, the concrete has been particularly susceptible to weathering and freeze-thaw damage.

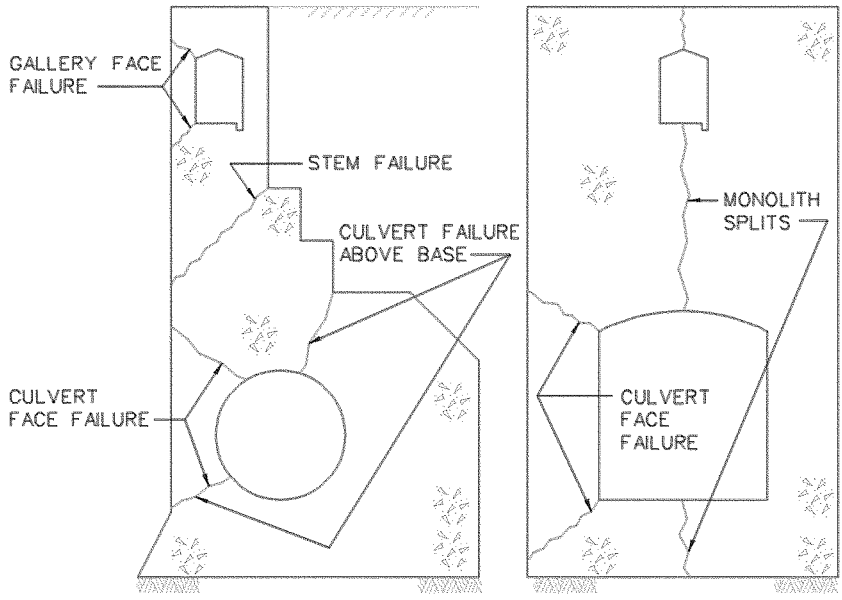
5. There are concerns about the long-term effectiveness of past major rehabilitations on the lock and approach walls at EDM. Prior to the major rehabilitation effort at EDM, horizontal and vertical surfaces of these walls were in advanced stages of deterioration and there were concerns about the stability of various wall sections. Degraded vertical and horizontal faces were removed, and a 12" overlay of new concrete was provided in an attempt to prevent water from reaching the interior concrete and thereby retard deterioration rates. However, field observations at these three projects indicate that water is reaching the deteriorated concrete, causing the concrete to become saturated and susceptible to additional deterioration. There were also stability concerns with the lock chamber walls at each of these projects that were addressed through installation of numerous "passive" anchors in the lock walls to resist movements. Passive anchors only provide resistance after movement of the monolith occurs. Further, these anchors were not designed to provide a long-term solution to wall stability, but were expected to extend reliable stability for at most 25 years. As these rehabilitations occurred during the 1980's, it is anticipated that any significant beneficial effects of the anchors can not be relied on beyond 2010 or so.

6. Following years of different attempts at estimating concrete structural reliability at EDM, including the possible development of analytical models and expert elicitation, it was decided that a condition assessment of these three projects and expert elicitation were the appropriate tools to complete this essential task. In September of 2000 a five-person panel of experts was assembled to estimate the current and future reliability of the structures on the Upper Ohio (Expert Elicitation For Concrete Monoliths at Emsworth, Dashields and Montgomery Locks and Dams, Ohio River). The expert elicitation process established probabilities of failures, the potential consequences for various failure modes and estimated the impacts to the expected service life of several repair or replacement options for concrete wall sections.[5]

[5] For a summary of the EDM Condition Assessment and Expert Elicitation, refer to the Engineering Appendix, Sections …

FIGURE 6-3

Concrete Monolith Failure Modes Considered For Walls At Emsworth, Dashields, And Montgomery Locks.



7. Other specific major reliability concerns at the existing Ohio River facilities are the lock miter gates (Markland, McAlpine, Greenup, and Meldahl) the dam gates, associated operation machinery and scour protection below the stilling basins at Emsworth, and erosion of the scour protection below J.T. Myers dam. Major Rehabilitation and Evaluation Reports (MRERs) have been approved by HQUSACE for the Markland lock gates and the dam gates and scour protection at Emsworth as noted in **Table 3.1**. These problem areas are summarized below. See the Engineering Appendix for more details.

8. The major problem at Markland is the potential loss of service of the main lock due to the condition of the miter gates and the subsequent impact to Ohio River navigation. Major girders in the lock gates at Markland have visible cracks. Serious concern regarding the integrity of the miter gates at Markland arose during a scheduled maintenance dewatering in 1994. This dewatering was scheduled to do major maintenance for the main chamber, including jacking the miter gates and replacing the pintle, seals, etc. However, once the chamber was dewatered and the gates were inspected, severe cracking at several locations was noted. The recommended plan in the Markland MRER includes replacement of the main lock miter gates at the earliest possible time and replacement of the main lock culvert valves at the same time. The lock gates at Meldahl, Greenup, Pike Island and New

Cumberland were designed using similar criteria and were constructed with similar welding methods.

9. The dam gates at Emsworth are difficult to operate and subject to failures of electrical truck mechanisms that guide the gates up and down. Beginning in 1998, operation of the dam gates has been plagued by failures of the bottom truck assemblies. Out of a total of 52 truck assemblies on 13 gates, 16 assemblies on 8 gates have required emergency repairs between 1998 and 2001. Sections of the scour protection installed during the Major Rehabilitation in the 1980's have already been damaged. Left unchecked, the dam apron and stilling basin could have been undermined which in turn would have threatened the integrity of the entire gated dam structure. The Emsworth Dam MRER recommended replacement of 13 dam gates on the main and back channel dams and reconstruction of the scour protection below each dam. The Pittsburgh District began Preconstruction Engineering and Design studies in 2004, with replacement of gates on the back channel dam scheduled to begin in 2006. All gate and stilling basin work at both dams is scheduled to be completed by 2011.

10. There is considerable erosion of the original concrete slab stilling basins, dam piers, and baffle blocks just downstream of the J.T. Myers dam. Recent hydrographic surveys and dive inspections, combined with underwater sonic camera imaging, have indicated some large holes in the stilling basin slabs at various locations. Continued erosion will not only render the dewatering system ineffective, but also threaten the overall integrity of the dam. In addition, there are other areas of concern regarding the condition of the dam including the dam tainter gate trunnion anchorages, the tainter gate cable connections, and mechanical/electrical equipment. The MRER for J.T. Myers dam was completed in July 2007 with a projected completion date of 2008.

6.3.3 Operational Efficiency Opportunities

1. The capacity of any project can be enhanced through more efficient operation, or "traffic management" measures. Traffic management is a fairly inclusive term encompassing all waterway transportation nonstructural alternatives. These relate to technical measures that increase the throughput of the system of locks and dams, as well as those measures that provide the lowest cost to users who value the system most. The first group of measures can be thought of as supply management and the later as demand management. Examples of supply management include tow sequencing lockage policies, the use of tow haulage equipment, and helper-boat operations. Each increase the throughput of the lock over processing tows on a first come first served policy. Demand management policies seek to alter shipper behavior either by making user costs more closely approximate the true economic cost of using the transportation system or by educating users on the external costs so they will act as though the external costs are reflected in the price. Examples of demand management include tow size restriction, traffic scheduling, congestion fees, and tradable lockage permits.[6] These measures do not

[6] Much of the literature on demand management of transportation systems is concerned with overland modes, most notably highways where external costs – accidents, road wear, congestion, noise, pollution, degraded living conditions in communities – are judged to be significant and not reflected in the cost of the highway system, therefore leading to over-consumption of this service. In this literature, the goal is to offer competition, choice, cost-based pricing (unless subsidy is justified) and economic neutrality. Waterways are regarded as a means of offering choice and competition in the movement of freight.

increase throughput, but do offer the potential to lower traffic delays by moving shippers away from congested shipping periods, which on the Ohio River System occur during unexpected lock chamber outages due to accidents, weather, or lock equipment malfunctions, or during planned lock chamber closures for repair or preventative maintenance. An objective of this study is to identify such measures that will ensure the most efficient operation of the ORS during all times, including those times when a main chamber is closed.

2. As previously discussed, the greatest delays to navigation occur during closures of main chambers. Both the Corps and industry take steps to minimize the adverse economic impacts of added delays during these times. The Corps attempts to reduce delays during main chamber closures in a number of ways. One is to meet with industry well in advance of any lengthy closures to discuss particular concerns involving the specific work activities and coordinate operations with navigation requirements as practical. During the closures, the Corps adopts an N-up/N-down lockage policy after queues of tows develop on both sides of the lock. N-up/N-down policy saves time over the "first-come-first served" policy used during most times when both chambers are operational for appropriate values of "N"[7]. For most Ohio River projects, N is set at 6, except at EDM where N is set at 3 since each tow is limited to 5 cuts through due to the extremely small size of the auxiliary locks. This arrangement is coordinated with industry before each extended main chamber closure. Industry also helps during these times of heavy congestion through a voluntary self-help program where towboats assist tows moving in the opposite direction by pulling out the unpowered cuts from the auxiliary chamber which in turn reduces the total lockage times. Pleasure boating is discouraged during main chamber closures but recreation lockages during these times are made when possible.

6.4 PROBLEMS AND OPPORTUNITIES RELATED TO ENVIRONMENTAL SUSTAINABILITY

1. Problems and Opportunities addressed in this SIP/PEIS report for environmental sustainability can be characterized as:

(1) Ensuring factors adversely affecting long-term sustainability of environmental resources are identified, controlled and addressed; and
(2) Identifying ways to enhance sustainability of aquatic and riparian ecological resources.

2. As stated in Section 6.2, one of the three main objectives for the ORMSS is to enhance Environmental Sustainability through identifying means within the authorities of the Corps of Engineers (or other agencies) to minimize degradation of environmental resources which might be caused by transportation or other development, and to improve

[7] Due to characteristics that may vary from lock to lock, the time required for a "turn back" lockage (or lockage in the same direction as the lockage immediately preceding it) may be less than the time required for locking succeeding tows in the opposite direction. N-up/N-down takes advantage of that time savings by locking N tows in one direction, then N tows in the other, when there are queues on either side of the lock.

sustainability of resources in and along the Ohio River. The Corps of Engineers Environmental Operating Principles define environmental sustainability as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations."

3. This section provides an overview of the study processes and presents areas of environmental concern. Section 6.5 includes more detailed information on opportunities and tools for addressing these concerns.

6.4.1 Identification of Environmental Sustainability Concerns and Opportunities

1. In accordance with the Council on Environmental Quality (CEQ) guidance, the CEA developed for ORMSS assessed the full direct, indirect, and contributed impacts of future modernization of the Ohio River mainstem navigation system on ten valued environmental components (VEC): water quality, fish, mussels, riparian/floodplain resources (RFR), air, health & safety, recreation, transportation & traffic, socioeconomics, and cultural resources. These assessments can be read in more detail in Section 10.2.2 of this report and in their entirety in the Environmental Appendix. The CEA holistically assessed the environmental sustainability (ES) of each VEC as an "ultimate test" for determining the significance of cumulative effects. The resulting ES findings and the actions subsequently identified form the basis for identifying problem areas and potential opportunities to address them.

2. To determine ES status, it was necessary to define ES categories. The general template used is as follows:

- Not sustainable (NS) – The composite conditions of the selected indicators do not reflect conditions that can sustain the resource over the long-term.

- Marginally sustainable (MS) – The composite conditions for the selected indicators are such that the resource can be sustained for the majority of river miles in or along the Ohio mainstem, but conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences.

- Sustainable (S) – The composite conditions of the selected indicators reflect sustainability for essentially all the river miles in or along the Ohio mainstem. Further, conditions of the indicators exceed regulatory thresholds and pertinent governmental programs are in place to support the resource.

3. ES categories of the various VECs were derived by combining the best professional judgment of the study team and from information developed by IWG members on the cumulative effects of multiple actions (i.e. Reasonably Foreseeable Future Actions, or RFFAs) as manifested through information available on indicators selected for each VEC. Although ES categories are somewhat qualitative, they are based on thorough analyses of past and present conditions as well as future conditions related to trends, plans, laws, regulatory programs and other sources of information.

6.4.1.1 Environmental Sustainability of Priority VECs

1. Of the ten VEC chapters described above, ongoing analysis and review discussions identified six that were of higher priority: Water and Sediment Quality, Fish, Mussels, Riparian/Floodplain Resources, Health and Safety, and Recreation. Reasons for assigning higher priority to these VECs included: relative importance or value of the component (e.g., water quality is essential to aquatic life, recreation and other uses), sensitivity of the VEC to ongoing factors affecting the sustainability of the component and sensitivity to changes related to commercial navigation on the Ohio River.

2. These priority VECs also displayed significant interdependencies or sensitivity to related influences. In this context, ES values of certain VECs become important "drivers" that influence ES values of other VECs in the overall system. Most notably, dramatic improvements in ES of the Water Quality VEC, have driven the other components of the aquatic ecosystem of the Ohio River toward increased ES. The ES of fish has measurably improved, while ES of riparian resources and mussels have benefited to a lesser extent. Cleaner water and improved aquatic resources in turn have enhanced recreational boating and fishing on the mainstem and stimulated growth of related support facilities such as marinas. Cleaner water nationwide also has contributed to a trend toward increased development and use of trails, greenways and other recreational facilities along rivers, including the Ohio mainstem. Such recreation facilities often stimulate riverfront development, including restaurants and entertainment districts, which add to local economic growth, but concomitantly contribute to loss of RFR and cultural resources.

3. H&S represents a VEC with improved ES in recent decades (due to improved water quality and more stringent workplace regulations), but with the potential for its ES to be driven downward by complex interactions with other VECs. Possible growth of commercial navigation, recreational activity, river-oriented industries, and other river users will require vigilance in management and regulation of H&S issues just to maintain the status quo.

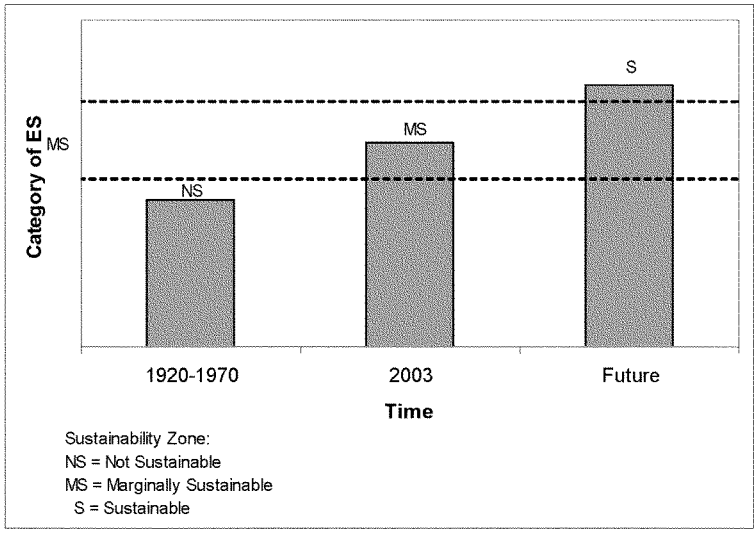
4. ES values of RFR and mussels are particularly confounding in part because of somewhat limited knowledge of these VECs. Regarding RFR, lack of knowledge until recently was correlated with the relatively low value assigned to these resources. Although interest in RFR has increased, these resources present a challenging complex of biogeochemical, hydrological and ecological processes. Similarly, Ohio River mussels are challenging to study, despite the fact that information on Ohio River mussels has been collected since the 1800s. Scientists studying mussels are hampered not only by lack of knowledge of reproductive cycles and habitats needs, but also by increased water depths due to impoundment of the river. Figures 6-4 through 6-9 below summarize the past, present and future ES conditions of the six priority VECs.

6.4.1.1.1 Water and Sediment Quality VEC

1. Due to the programs of ORSANCO, and requirements of the Federal Water Pollution Control Act (FWPCA) (and the amended Clean Water Act (CWA)), the water quality of the Ohio River has shown a steady improvement in recent decades. For example, DO concentrations are typically above the 5.0 mg/L standard, pH levels are between the 6.0 to 9.0 standard, and nitrogen concentrations meet current water quality criteria. However, continuing concerns include bacterial contamination primarily associated with non-point source (NPS) pollution downstream from major urban areas, legacy "contaminated sediments" in the upper river, and fish consumption advisories throughout the mainstem. Accordingly, although there are many positive signs, the ES of the water quality VEC is classified as having improved from an historic status of "unsustainable" to the present status of "marginally sustainable".

2. Regarding the future, it is expected that water quality of the Ohio River mainstem will further improve with continuation of source control and other pollution reduction programs. Therefore, it is anticipated that the ES of water quality will achieve a "sustainable" condition. However, vigilant efforts are still needed to continue effective water quality and aquatic ecological monitoring and management efforts. Actions expected to be beneficial to water quality in the future include implementation of nonstructural navigation improvements and technological improvements related to communications and more environmentally-advanced barge design. Activities that support commercial navigation (e.g. port development and maintenance dredging) will continue to be scrutinized by regulatory agencies and nongovernmental organizations (NGOs) and may be more strictly regulated. Much development activity, however, will involve conversion of existing floodplain lands that now afford habitat protection, open space and ecosystem values. Once converted, such lands are unlikely to revert to their former more natural states. Increasing emphasis on pollution prevention, erosion control best management practices (BMPs), and implementation of the Phase 1 and 2 National Pollutant Discharge Elimination System (NPDES) programs could counteract some adverse impacts, particularly in more urban areas. In general, several regulatory initiatives in recent years should measurably improve water and sediment quality, but it is not possible to predict the magnitude of their beneficial effects.

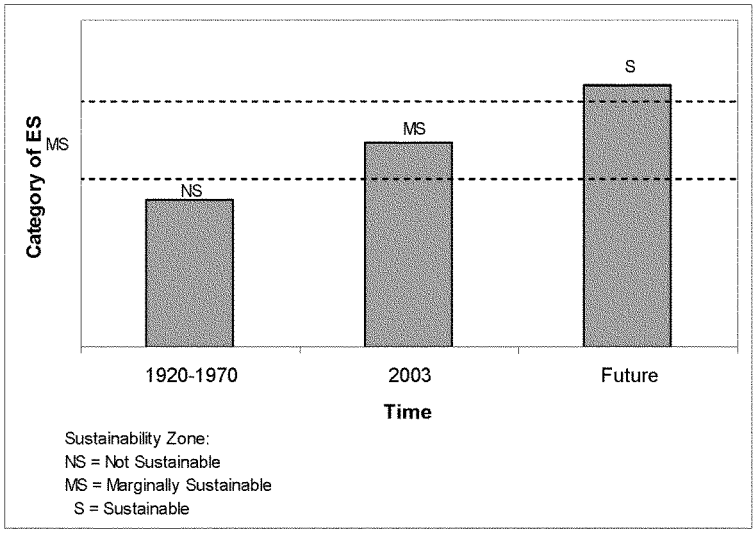
FIGURE 6-4
ES of Water Quality



6.4.1.1.2 Fish VEC

1. Prior to1920 and continuing well into the mid-20th century, fish communities became severely degraded, especially in the upper and middle reaches of the river, as reflected in the decline of many native species and the increase in pollution tolerant species. From the mid-20th century until the present time, improvements in the sustainability of the fish resource have been observed throughout the mainstem. Such improvements have resulted primarily from initiatives by ORSANCO, efforts of the six Ohio River states, and the requirements of the Federal Water Pollution Control Act (FWPCA) and the amended Clean Water Act (CWA). Concurrent with improvements in water quality, however, has been the continued inundation of fish habitat and impediments to fish passage not only from navigation structures constructed before 1950, but also from continuing construction and operation of additional high-lift dams. The modern navigation system, combined with land use and flood control practices in the watershed, has caused the inundation and siltation of extensive areas with gravel substrate, preferred by many migratory fishes. Also, the barriers to fish migration created by the dams may have disproportionately affected the native migratory fish that have not been documented to use the lock chambers to move between pools. This fish assemblage, referred to as the Great River Fishes, has not recovered and represents a subset of the fish resource that is currently at less than a sustainable condition. Two major uncertainties emerged during the last decade that may affect the fish resource into the future: 1) the invasion of four Asian carp species and 2) the invasion and unknown population dynamics of zebra mussels, which seriously impact native mussels, an important food resource for many fish species. Accordingly, the ES of the fish resource as a whole at present is classified as having improved from "unsustainable" to "marginally sustainable."

FIGURE 6-5
ES of Fish Communities

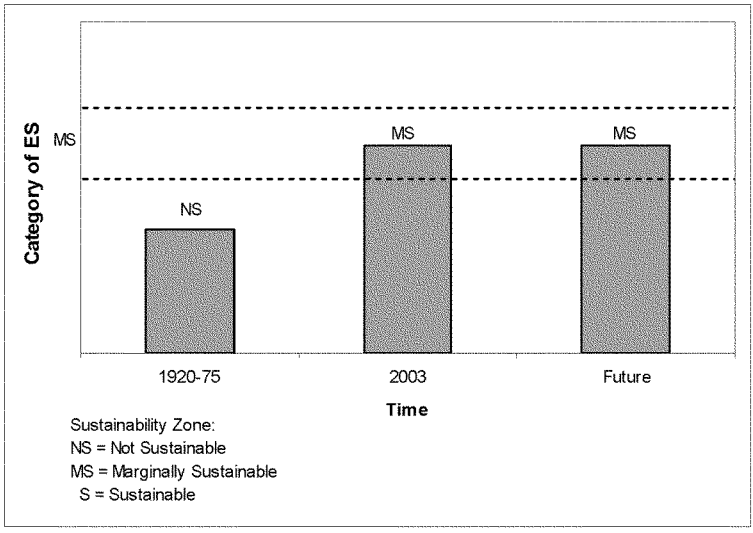


2. Regarding the long-term future, regulatory requirements and pollution control programs have been implemented that will benefit the fish resource, if continued into the future. Given recent improvements in the resource, the development of new assessment tools, and the level of stakeholder interest, it is expected that fish communities of the Ohio River mainstem will attain a "sustainable" condition and may further improve with long-term elimination of combined sewer overflows and better nonpoint pollution control. The habitat effects of impoundment of the river are expected to persist into the future, but ecosystem improvement measures may counteract such effects and to produce habitat benefits and enhance interpool connectivity. Concerning the Great River Fishes, for which the future sustainability is uncertain, removal of migratory barriers through operational or structural measures would be an important contribution toward improving their status. Fish passage strategies will be studied at site specific projects recommended in this study to address the sustainability goal for this assemblage.

6.4.1.1.3 Mussels

1. In the time period from 1920, and continuing up to the mid-point of the last half of the 20th century, the ES of freshwater mussels in the mainstem was in a continuing decline and thus classified as "not sustainable". Numerous actions contributed to the decline, including, but not limited to, acid mine drainage in the upper river, high-lift locks and dams disrupting mussel and fish-host migration, numerous discharges of untreated to partially treated municipal and industrial wastewaters, in-stream sand and gravel mining, dredging for new ports and terminals, periodic maintenance dredging for the navigation system, mussel harvesting for button manufacturing and the cultured pearl industry, and multiple land use changes resulting in increased nonpoint source pollution.

FIGURE 6-6
ES of Mussel Resources



2. In the time period from 1975 up to 2003, some improvements in sustainability of the mussel resource in the mainstem were noted, although improvements were typically localized and exhibit frequent fluctuations. Conversely, there has also been a general reduction in number of mussel beds since about 1975. Improvements that have occurred resulted from 1) reduced acid mine drainage in the upper river, 2) enhanced treatment requirements for municipal and industrial wastewater treatment plant discharges, 3) consideration of mussel bed locations in river-related permitting programs (e.g., Section 404 and Section 10 permits) and navigation system operational features (location of queuing and barge fleeting/storage areas, and placement of dredged material), and 4) protection provided through designation of several mussel species as threatened or endangered under the Endangered Species Act (ESA) and similar state protective mechanisms. The current designation of "marginally sustainable" is appropriate considering that composite conditions for the selected Ecological Sustainability indicators are such that diverse mussel populations are occurring only along some segments and in some pools of the river and that conditions of the indicators are somewhat tenuous both in location and likelihood of occurrence. The conditions also reflect a continuing level of uncertainty regarding appropriate quantitative measures of the Ecological Sustainability of freshwater mussels.

3. Regarding the future, as additional regulatory requirements and pollution control programs are implemented, mussel habitat conditions should be more conducive to reproductive success and community connectivity than at present. Of particular importance is the need to integrate considerations of mussel beds and the life cycle features of mussels into permitting and other locational decisions within or along the mainstem. As further mussel monitoring and research is conducted, these data should be added to

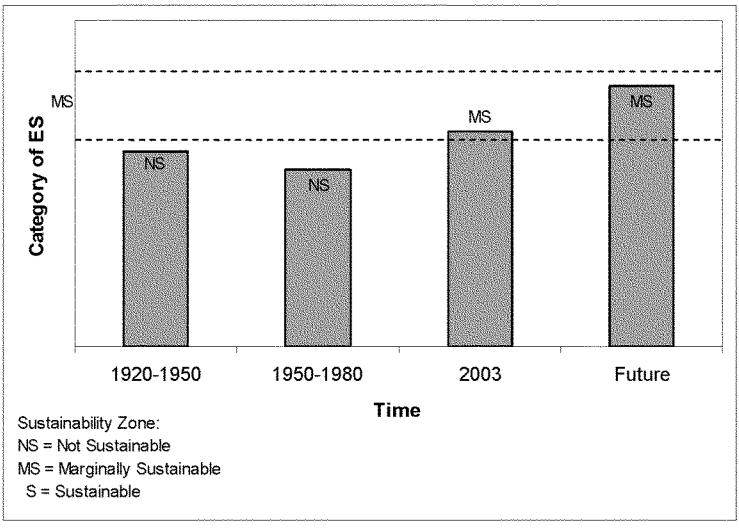
existing databases to provide further information for both protecting and promoting mussels. Equally as important is developing operational and structural strategies for fish passage through the navigational structures to allow fish hosts to freely move between pools for the purpose of recolonizing mussel beds and increasing numeric abundance. Further, consideration should be given to implementation of an integrated adaptive management program for the Ohio River freshwater mussels. This assessment of future marginal sustainability acknowledges that many unknowns remain and that recovery of the Ohio River mainstem native mussel populations will be a long-term process involving many years of collaborative efforts and monitoring. One of the major unknowns is the effect zebra mussels will exert on native mussels in the future. Evidence of recruitment and population stability is necessary to validate viability.

6.4.1.1.4 Riparian/Floodplain Resources

1. In the time period prior to 1920, and continuing up to about 1950, the riparian/floodplain resource (RFR) can be classified as "not sustainable" due to relatively rapid losses of riparian habitats and their functions, the lack of knowledge of the importance of these resources to both terrestrial and aquatic ecosystems, and the essential absence of any institutional programs to manage or control riparian areas. In the time period from 1950 to 2000, worsened "not sustainable" conditions occurred in the first several decades as a result of still more disruptions and losses of riparian areas. However, recent decades have included an increasing awareness of riparian services, including regulation of wetlands, a highly productive riparian component. The establishment of the Ohio River Islands National Wildlife Refuge has focused attention on the disappearance of another riparian habitat type, islands, and has heightened visibility of the riparian resources of the Ohio mainstem embayments. These initiatives suggest the current status of RFR may be moving toward "marginally sustainable." Accompanying these initiatives is an increasing recognition that institutional programs must be established to protect RFR.

2. Regarding the future, the growing awareness of environmental services performed by RFR such as flood risk reduction downstream and reduction of stream bed scouring for mussels, as well as increasing demand for river corridor enhancement and protection for passive recreation may help move RFR toward a more sustainable future. However, it is less certain if environmental regulations and institutional programs will be in place to support RFR sustainability and stem fragmentation and loss of RFR from development along the Ohio River mainstem. Accordingly, the future ES of RFR is classified as "marginally sustainable."

FIGURE 6-7
ES of Riparian/Floodplain Resources



6.4.1.1.5 Health and Safety

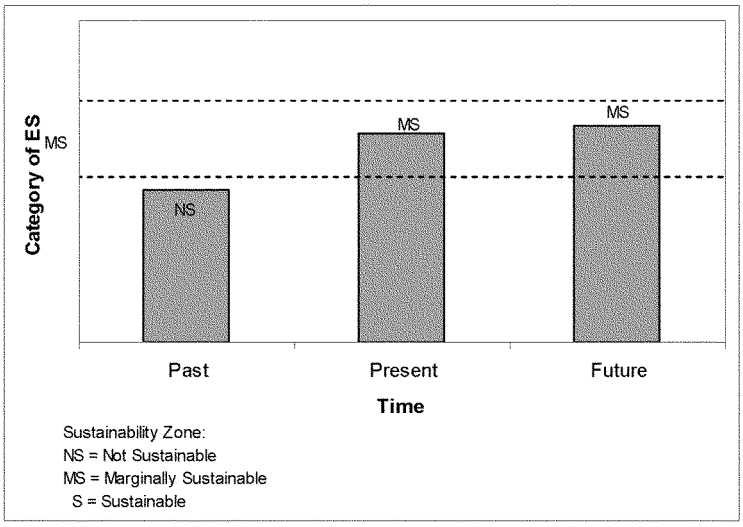
1. In the time period prior to 1920 and continuing into the 1960-70s, health and safety (H&S) issues on the Ohio River represented a broad spectrum of risk factors. Construction and workplace conditions were generally more dangerous than at present; spills and discharges from commercial navigation, river oriented industries, and untreated municipal effluents contributed to a variety of public health risks; and little or no information was available to advise the public of ambient risk levels associated with river oriented activity.

2. While individual risk factors no doubt varied significantly from time to time, most H&S related issues for the period are categorized as 'marginally sustainable.' However, activities that involved more direct exposure to water quality risk factors are categorized as 'not sustainable' in **Figure 6-8**.

3. Improvements to water quality, reduced risks of spills and faster response, improved workplace safety standards, and effective safety standards for recreational boating have all combined to make the Ohio River a safer place to work, live, and play. These improved present day conditions result in a 'sustainable' classification for some H&S related issues. Improved conditions have also contributed to reduce risk factors associated with contact recreation and fish consumption. However, problems associated with continued exceedances of biological standards, the persistence of some contaminants associated with fish consumption, and mixed signals regarding fish consumption standards result in a present time classification of 'marginally sustainable' for these activities.

4. With respect to the future, some H&S issues are expected to remain in the 'sustainable' rankings. It is important to note, however, that continued growth of commercial navigation, recreational activity, river oriented industries, and other uses of the river will require continued improvements in management and regulation of H&S issues just to maintain the status quo.

FIGURE 6-8
ES of Health & Safety for Contact Recreation and Fish Consumption



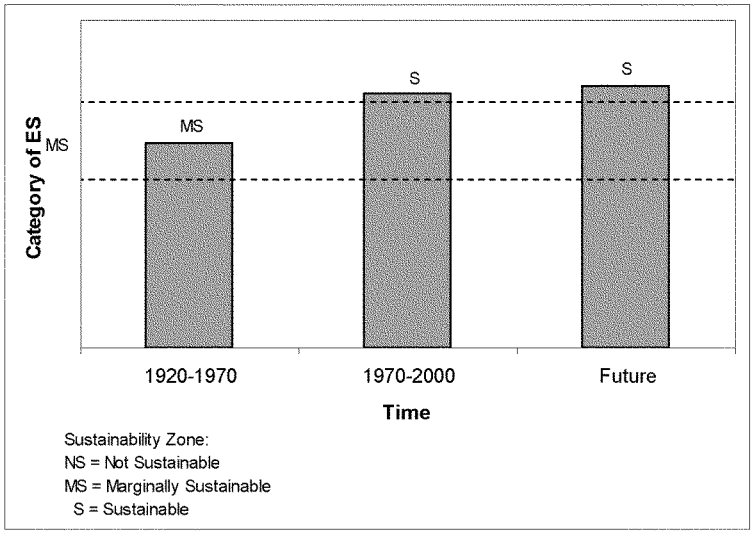
5. While improvement of risk factors associated with contact recreation and fish consumption is expected to continue, these factors are kept in the 'marginally sustainable' category as a conservative estimate of potential trends. Some efforts required for continued improvement, such as rehabilitation of sanitary sewer systems to eliminate combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) or reduction of mercury emissions from coal combustion, will require significant investments and long periods of time to achieve results.

6.4.1.1.6 Recreation

1. In the time period prior to 1920, and continuing up to about 1950, recreation on the Ohio River occurred in a degraded environment due to largely untreated and uncontrolled pollution discharges from growing municipalities, mining activity, and various types of industries and land uses along the river. Although the river continued to be used for recreation during this period, the overall ES was "marginally sustainable" and may have been "not sustainable" for the worst years of pollution. However, recreation information from the worst decades of pollution is limited as that time period coincided with the Great Depression, World War II, and the post-war period shortly thereafter, when leisure time and financial resources were limited.

2. At the present time, recreation on the Ohio River is currently in a "sustainable" condition due in large measure to water quality improvements related to ORSANCO programs and requirements of the FWPCA (and the amended CWA). Water quality improvements, combined with increased economic prosperity, have increased the demand for and stimulated the development of marinas, ramps and other recreation facilities along the river. The recent era of more integrated riverfront planning also has addressed recreation needs and has increased opportunities for an expanded spectrum of recreational choices.

FIGURE 6-9
ES of Recreational Resources



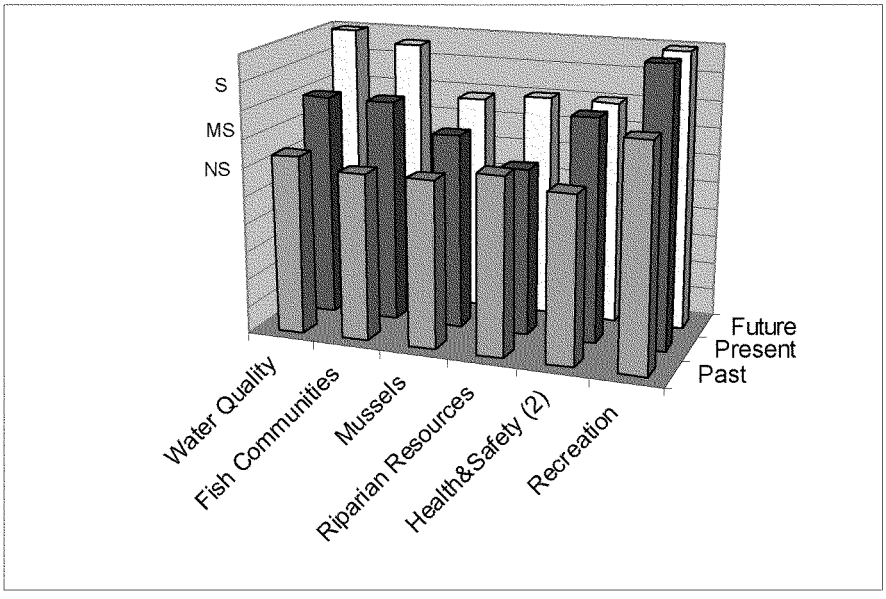
3. Regarding the future, it is expected that community planning and development of recreation facilities, further water quality improvements, especially in stormwater and CSO management, and habitat protection and restoration efforts will continue to enhance recreation experiences. Socioeconomic projections for a stable or slowly growing population and continued improving standard of living would be expected to result in continued growth of demand for recreational opportunity. Consequently, the future ES is classified as "sustainable." Although the perception exists that increased participation could lead to overcrowding and competition for limited resources, it does not currently seem to be an overriding influence affecting people's decisions to participate in river-related activities.

6.4.1.2 VEC Interdependencies

1. As suggested in Section 6.4.1.1, analysis of sustainability needs suggested a high degree of linkages and interdependencies. For example, barriers to fish passage have significant impacts on recolonization of mussel beds which are further subjected to

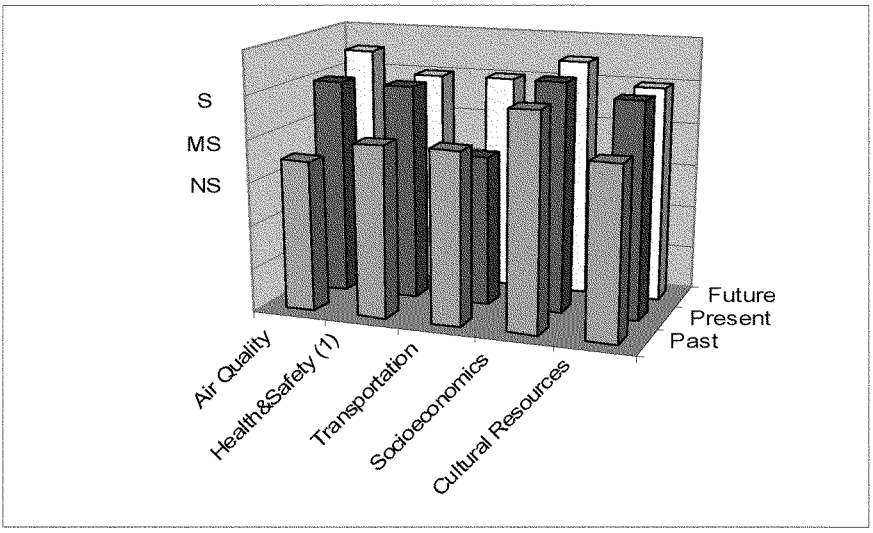
increased scouring resulting from disturbed riparian areas. Figures 6-10 and 6-11 below summarize the past, present and future ES conditions of the ten VECs and are discussed in detail in the CEA report in Appendix A. The VECs are divided into two groups to improve viewability of the graphs. Group 1 includes those resources that are potentially more sensitive to changes related to commercial navigation on the Ohio River. Analysis of the Health and Safety VEC resulted in the reporting of two ES trends. Health and Safety (2) refers to fish consumption advisories and direct contact with river water (e.g. swimming or boating). All other issues addressed by this VEC are included in Health and Safety (1).

FIGURE 6-10
ES Trends for VEC Group 1



Sustainability Scale: Taller columns represent greater sustainability. NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range.

FIGURE 6-11
ES Trends for VEC Group 2



Sustainability Scale: Taller columns represent greater sustainability. NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range.

2. Sustainability concerns identified in the CEA Report are presented in **Table 6-4**. It should be noted that some concerns apply to more than one VEC. CSOs, for example, affect Water Quality, Health & Safety and Recreation and also have effects on Fish, Mussels and Riparian Resources. Addressing such complex issues will require long-term collaboration, but can lead to major gains in the river's long-term sustainability.

3. Opportunities to enhance Environmental Sustainability of VECs through existing regulatory efforts, educational programs and various existing authorized programs were identified and offer positive signs for sustainability of several VECs. The continuation or success of such efforts and trends, however, needs to be monitored and must be reinforced through continued support of the public.

TABLE 6-4
Sustainability Concerns

Water Quality & Sediment Quality
1) Legacy contaminated sediments
2) Bacterial contamination from CSOs
3) Continued development in riparian areas

Fish
Asian carp species moving upriver

Mussels
1) Incomplete knowledge of life histories for species of concern, including life histories of host fishes.
2) Protection of mussel habitat
3) Habitat degradation
4) Species of concern extirpation or population reduction
5) Lack of resources to enforce all laws and regulations pertaining to collection of specimens and protection of habitat.
6) Zebra mussel and Asian carp invasions.
7) Lack of public and agency awareness of existing laws that protect mussels.

Riparian/Floodplain Resources
1) Continued fragmentation and loss of riparian resources
2) Need for institutional coordination for riparian area management, including:
    a. Requiring impact identification and mitigation through NEPA
    b. Designation of special management areas on public lands
    c. Regulation of activities on privately-owned riparian areas
    d. Utilization of incentives to encourage use of BMPs, and
    e. Purchase of privately owned lands for public management

Air
Establishment of more effective limits for mercury emissions

Health & Safety
1) Growing potential conflicts among recreation, commercial and navigation river users
2) Need to eliminate CSOs and SSOs
3) Reduction of mercury emissions from coal-fired power plants
4) Clarification of fish consumption advisories

Recreation
1) Need to eliminate CSOs and SSOs
2) Perception that increased participation could result in overcrowding and competition for limited resources

Transportation &Traffic
1) Competition over time between navigation and recreation vessels for use of locks
2) Amounts and types of fuels used by tows

Socioeconomics
Need to balance long-term growth of navigation with infrastructure that supports it.

6.4.2 Environmental Sustainability Concerns and Opportunities For Ohio River Aquatic and Riparian Resources

1. During the course of this study, the Corps assembled a team of national and regional experts on the topic of aquatic and riparian resources of the Ohio River. Through a series of workshops, the group identified the ecological functions that have been compromised along the river and possible causes of such compromises. Many of the specific problems were listed in **Table 6-4**. Those subject matter experts were then asked to describe attributes of a desirable state for ecological resources. Next, the groups were asked what actions were needed to move the resources toward the desirable state. The group was not constrained by how the actions might come about or who would implement those actions; however the resulting list provides a means or concept plan for meeting sustainability needs. The measures identified are listed in **Table 6-5** below. It is important to note that the actions identified were focused solely on needs of aquatic and riparian resources, and that no single agency or organization has the authority or responsibility for implementing all of these actions. Rather, all interested parties could work cooperatively to undertake specific actions that would contribute to improving resource sustainability.

TABLE 6-5
Opportunities for Enhancing Ecosystem Sustainability

Enhance fish passage around or through dams
Dismantle unneeded federal tributary dams
Dismantle unneeded non-federal tributary dams
Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats
Allow flows to mimic natural regimes including seasonal and extreme floods and droughts
Restore unique mainstem habitats such as canebrakes, river bluffs and mussel beds
Protect tailwaters and provide structures to serve as refugia for fish
Create spawning shoals and other in-stream features to enhance habitat diversity in navigation pools
Identify and expand areas of submerged and emergent aquatic vegetation
Protect and manage mussel populations and their habitat on a site-specific basis
Mark critical locations to prevent mooring near mussel beds or special shoreline areas
Mark shallow mussel beds to reduce direct impacts of tow traffic
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources
Protect existing aquatic habitats, restore lost habitats and diminished resources
Reintroduce native fauna and expand the range and populations of native fauna from reduced levels
Control exotics, including minimization of existing populations and prevention of new introductions
Reduce bacterial contamination from combined sewer overflows
Address point and non-point sources affecting aquatic nutrient balance
Minimize catastrophic contamination events through reduction of spills, accidents, and improvement of spill response procedures
Continue remediation of CERCLA, brownfields, and other contaminated sites
Reconnect and restore streams with floodplains on the mainstem and tributaries
Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries

2. The above list of needed actions primarily includes approaches that address restoration of habitat variety, recovery of 'missing' habitat components, reestablishing functions and connectivity, removing outdated infrastructure, and generally finding ways of compensating for the effects of infrastructure that must remain. The expertise of the Corps of Engineers stemming from development and long term operation and maintenance of the Ohio River Basin's navigation and flood control infrastructure would provide a valuable source of expertise to the planning, design and implementation of these holistic approaches to ecosystem restoration.

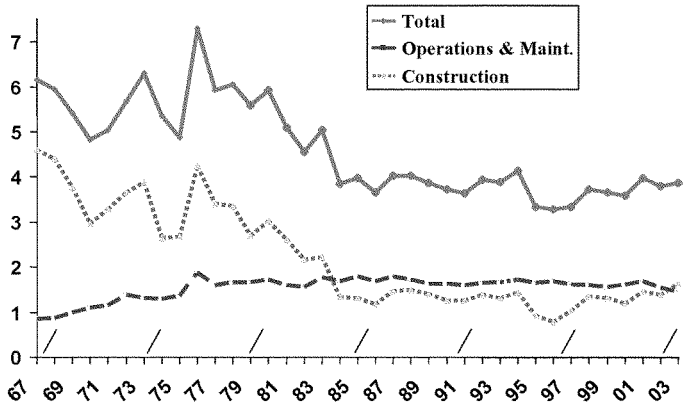
6.5 INVESTMENT OPTIONS

This section provides an introduction to possible solutions to the above problems and ways to realize opportunities. Investment options, or measures, addressing future navigability and navigation efficiency objectives are grouped into three categories, from least to more expensive: (1) maintenance, (2) low-cost structural and operational, and (3) major structural improvements. Additional investment options that address the environmental sustainability objective are described in Section 6.5.5.

6.5.1 Continued Navigation Planning

1. As stewards of the nation's inland navigation assets, the Corps of Engineers, in partnership with navigation and resource agency stakeholders, strives to maintain an inland waterway system capable of handling transportation demands in an efficient, reliable and environmentally sustainable manner. This role as stewards is even more critical on the Ohio River as over half of the navigation projects have or will soon exceed their 50-year design life. The Corps is striving to strengthen its role as navigation stewards through the establishment of the National Center of Expertise for Inland Navigation located in Huntington, WV. The Center's goal is to ensure that navigation projects receive the appropriate level of maintenance and modernization upgrades to effectively and efficiently meet system traffic demands on the waterways without compromising the environmental integrity of the river. Efforts to meet the high goals of this program are complicated by Federal funding levels that have declined dramatically in the 1980's and 1990s (**Figure 6-6**) and remain relatively low today compared with system infrastructure needs, thus hampering Corps efforts to maintain its existing infrastructure and to modernize with major structural improvements (such as larger locks). Constant or declining budgets make the heightened attention to the navigation system all the more necessary.

FIGURE 6-12
Civil Works Appropriations (1967-2003)
in Constant FY95 $Billions



2. The Center of Expertise for Inland Navigation will eventually apply the ORNIM methodology to all Ohio River mainstem dams, navigation structures on Ohio River navigable tributaries, and will continue to develop the metrics and gather the data to assess future traffic forecast scenarios. By tracking and updating the scenarios, the Corps will be able to apply the proper investment package (maintenance and upgrades) to the navigation system in order to maximize navigation benefits. Also included is consideration of potential impacts to environmental sustainability of the entire Ohio River system. Environmental Impacts will be assessed to help predict if any valued environmental components (VECs) are threatened by navigation-related activities in combination with actions by others that also affect the river environment. The Corps will continue to refine several aspects of the environmental models used in this study and will collect data to develop the input files for the navigable tributaries within the basin. For a more complete list of environmental efforts, see **Table 6-6**. On an ongoing basis, the Corps will consult with resource partners and will monitor the environmental metrics to ensure predicted sustainability trends are occurring.

3. Federal decisions regarding navigation based on this study should focus on "near term" actions requiring immediate action in order to implement the SIP. Follow-on studies will be recommended for major rehabilitations, lock improvements and managerial actions not currently covered by Corps authorities (i.e. congestion fees), or new authorities. Certain actions covered by Corps authority, such as improved operational procedures, maintenance items, low cost structural measures, or previously approved major rehabilitations could be implemented as soon as needed without further study, assuming that funds are made available. However, decisions for actions required in the longer term (i.e., not requiring immediate action) will be deferred and confirmed during future updates. At some point in the future, these long term actions could well become near term and follow-on studies recommended at a later date. Alternatively, actions not currently envisioned during the analysis period may surface during these updates.

4. Federal decisions regarding the environment should focus on two areas: 1) ensuring navigation improvements in combination with other reasonably foreseeable actions do not significantly degrade long-term resource sustainability and 2) taking all practical steps available to enhance sustainability. The first of these two can be accomplished through implementation of environmental components in **Table 6-6**. Means of enhancing environmental sustainability are discussed later in Section 6.6.

TABLE 6-6
Environmental Sustainability Strategies
Under the Navigation Stewardship Program

Strategy	Time Frame
Refine the NAVPAT model, especially the species curves, to reflect findings from traffic effects studies conducted by ERDC-WES since initial species curves were developed in the 1980s and develop capability to assess traffic effects on backchannels and embayments.	MONTHS 1-60
Develop NAVPAT module in ORNIM to perform equivalent to other modules, specifically to allow ORNIM to optimize environmental considerations along with economic and engineering.	MONTHS 1-60
Complete development of QUEPAT to evaluate near field traffic effects of tow queuing in proximity of Locks and Dams.	MONTHS 1-24
Pursue development of a model to assess traffic impacts to mussels	MONTHS 1-36
Periodically conduct substrate condition assessments	PERIODICALLY
Continue to update environmental data on freshwater mussel resources	ONGOING
Conduct periodic resurveys of water based recreational use of the river	MONTHS 108-120
Monitor riparian habitat condition	ONGOING
Maintain GIS databases and supplement with new data as available	ONGOING
Continue periodic interagency team meetings with resource agencies and others to communicate findings and evaluate sustainability conditions	ONGOING
Prepare additional cumulative effects assessments and NEPA supplements as needed	MONTHS 60-78

5. Refinement of the NAVPAT model, emphasizing fish guilds, rather than individual species curves, would reflect findings from traffic effects studies conducted by

the Engineering Research and Development Center-Waterways Experiment Station (ERDC-WES) since initial species curves were developed in the 1980s and would develop capability to assess traffic effects on backchannels and embayments. A NAVPAT module in ORNIM would perform equivalent to other modules, specifically to allow ORNIM to optimize environmental considerations along with economic and engineering. The QUEPAT model would evaluate near field traffic effects of tow queuing in proximity of Locks and Dams. No recreation studies, CEA, or NEPA supplements would be anticipated in the near term but these documents would be reviewed periodically in later years to determine if supplements are needed.

6. Environmental activities similar to those practiced on the Ohio River mainstem would be adapted for application on navigable tributaries as shown in **Table 6-7**. Additional species curves would be developed for select tributaries based on species occurrence. Characteristics of various resources would be defined and ecosystem sustainability needs for each tributary would be determined. Periodic tasks would include CEA and NEPA analyses and preparation of documents for investment plans

TABLE 6-7
Environmental Sustainability Strategies
Navigable Tributaries to the Ohio River

Collect NAVPAT/QUEPAT base data for tributaries
Develop additional species curves for selected tributaries based on species occurrence
Define characteristics of various resources of each tributary
Obtain or develop GIS databases
Determine ecosystem sustainability needs for each tributary
Conduct cumulative effects assessments and NEPA analyses and prepare documents for investment plans
Establish or supplement interagency team

6.5.2 Maintenance Measures for Navigation

These are maintenance policies designed to reduce closures times and/or to reduce the impacts of maintenance of the navigation system on waterway shipping. A list of maintenance measures considered includes:

- Routine and Cyclic Maintenance. One possible enhancement includes full implementation of the miter gate quick change-out system. This system is partially implemented, but full implementation would realize the maximum potential of reduction in closure durations due to miter gate maintenance. This scenario is still in development and will continue to be investigated since each project is in different stages and each district is still assessing this methodology.

- Replacement of major components, including the need for Major Rehabilitation.

6.5.3 Operational Efficiency and Low-Cost Structural Measures for Navigation

1. These are methods that involve largely operational and relatively low-cost structural measures generally costing less than $15 million, considerably less than lock expansion or new lock options. Examples of low cost and operational measures considered includes:

- Continuing an N-tow-up / N-tow-down lockage policy (queue discipline) whenever a Main chamber is closed. This procedure is already used whenever major maintenance occurs at any of these locks, where N is 3 at Emsworth, Dashields and Montgomery Ls/Ds on the upper river, and N is 6 at all other Ohio River Ls/Ds.

- Use of helper-tow boats to provide tow assists during Main-chamber shutdowns. This is generally accomplished through "industry self-help," whereby commercial motor vessels volunteer to aid other tows in making approaches or in pulling unpowered barge-cuts from the Auxiliary chamber. Industry provides this service during any extended (30 days or more) main chamber closure.

- Congestion fees. This procedure is not currently in use at any Corps project. Implementation would require additional authority.

- Traffic Management, including the scheduling, and/or rescheduling, of tows during chamber shutdowns. Industry currently adjusts their schedules voluntarily during main

chamber closures. This study considers the potential benefit of Corps mandated lockage times, particularly during closures of the main chamber when delays are most severe. Implementation beyond voluntary efforts by the towing industry would require additional authority.

- Providing mooring cells and /or buoys upstream or downstream of locks to reduce some approach and exit times. Facilities currently without mooring cells either downstream (DS), or both upstream and downstream from the locks (B) include: Willow Island (DS), Belleville (DS), Racine (DS), Greenup (DS), Meldahl (DS), McAlpine (B), and Smithland (B).

2. These same measures for decreasing delays at the locks by decreasing lockage times and reducing waiting times incurred by tows waiting to lock through will also lead to environmental sustainability improvements. Many of these practices are already in place to reduce traffic delays and tow queuing that can damage habitat and interfere with fish and mussel communities and other aquatic life, especially during prolonged lock closures. Others, such as new mooring cells, are considered further in this study as a feature of the without project condition. A mooring cell downstream of Greenup is included in the Auxiliary lock chamber extension authorized in WRDA 2000.

6.5.4 Lock Modernization Measures

1. Substantial delay reduction at any Ohio River lock (where that reduction cannot be provided through the use of non-structural and/or low-cost measures) is available only through major construction that increases lock capacity. Innovative construction techniques would be employed to allow much of the construction to take place "in-the-wet" (without cofferdams) and utilizing pre-fabricated float-in or "lift-in" lock segments. This would lessen the impact on on-going navigation at the existing site during construction by moving much of the construction off-site, as well as provide anticipated cost and time savings versus "traditional" methods. Based on previous study, two general types of major structural improvements were considered for Ohio River projects:

- At Emsworth, Dashields, and Montgomery, replacement of the existing auxiliary with either a 600'x110' or 1200'x110' chamber and possible reconstruction or enlargement of the existing 600'x110' chamber.

- At the remaining projects with 1200'x110' and 600'x110' chambers, the existing 600' chambers would be extended up to a maximum length of 1200'.

2. Detailed consideration of alternatives at any project and recommendations for lock modernizations will be deferred until site-specific Feasibility Studies. The measures cited above are specifically related to this SIP report.

6.5.5 Additional Environmental Sustainability Improvement Options

1. Section 6.2 (Planning Objectives) explained that the ORMSS study objective of enhancing environmental sustainability focuses on identifying and implementing measures within the authorities of the Corps of Engineers and other agencies to minimize degradation of environmental resources caused by transportation or other development, and to improve sustainability of resources along and in the Ohio River. Environmental sustainability seeks a balance between environmental and economic considerations to improve the quality of life for present and future generations. The integration of the economic and environmental aspects of the navigation system is an important focus in future navigation investment decisions.

2. Several opportunities for enhancing environmental sustainability already exist within the Corps of Engineers, the navigation industry, federal and state natural resources agencies, and non-governmental organizations. In addition, a new, more comprehensive approach, the Ohio River Ecosystem Restoration Program was authorized in 2001 and addresses environmental improvements specific to this river.

3. Studies and workshops conducted for the CEA resulted in a number of ecosystem restoration recommendations that could contribute to improved sustainability of aquatic and riparian resources of the Ohio River. These recommendations were previously listed in **Tables 6.4 and 6.5**. These activities included some additional components for enhancing environmental sustainability, such as agency coordination, monitoring, adaptive management, good environmental design and public education which are discussed in further detail in Chapter 13 of the CEA Report. Continuing dialogue concerning adaptive management and environmental sustainability issues at various forums should lead to new collaborative and creative ideas and projects.

4. Finally, there is potential for additional approaches to environmental sustainability on the Ohio River. As the opportunities are identified and assessed, if existing authorities do not exist, they can be requested. This applies not only to the Corps or Engineers but to all agencies with jurisdiction for resources along the river. Agencies can also adopt a new approach to mitigation for impacts associated with their actions to address sustainability concerns (i.e., sustainability-focused mitigation) as discussed later in section 10.4.1..

6.6 PLANNING CONSTRAINTS AND ASSUMPTIONS

Presented below are four constraints and three assumptions that have, in a sense, defined the range of options explored in this study. The first of these were implicit from the earliest stages of the Mainstem study.

Constraint 1: There Will Be No Change to Authorized Nine-Foot Draft Ohio River Channel

Deepening the Ohio River channel might be one way to increase the freight-handling capacity of the system (more tons per tow-surface-area). Since completion of the

Ohio River canalization project in 1929, the U.S. Government has maintained a 9-foot deep x 300-foot wide navigation channel between the lock and dam projects.

Deepening the channel would require combinations of the following:

- extensive and on-going dredging of long segments of the river, including areas currently not requiring maintenance dredging;
- raising the minimum "Normal Pool" levels – which would require modifications to many or all the lock and dam structures as well as other infrastructure (e.g., water intakes, bridges, etc.).

Thus, deepening of the channel was not considered for a number of reasons, particularly:

- No precedence for channel deepening has ever been established in recent Ohio River infrastructure feasibility reports (the Gallipolis, Olmsted and McAlpine authorization reports). All current structures and those under construction are designed expressly for an authorized 9-foot channel depth. The depth over the lock gate sill is designed for tows that accommodate this channel depth.
- There is no reason to believe such a deepening would be cost-effective, due to the associated expense of modifying 19 locks and dam structures to safely allow deeper drafted vessels to lock through.
- The environmental consequences of deepening, requiring dredging to levels well below current river strata, are assumed to result in a serious negative impact to river fish, wildlife, and plant-life. Also, the environmental impacts associated with disposal of large amounts of dredged materials would be a significant problem.

Constraint 2: Maximum Lock Size Considered is 1200' L. x 110' W. (nominal dimensions)

Constraint 2 is in some ways similar to constraint 1 in that it is governed by the natural geometry of the river itself. Locks larger than the nominal size of 110' wide x 1200' long were not considered, based on previous input from commercial navigation interests, as well as being consistent with the existing maximum lock chamber sizes currently in use.

Natural river geometry tends to limit tow sizes to about 108' wide x 1200' long along most of the river, particularly in bend-way areas. Occasionally, a few companies run double-wide (30-barge) tows along portions of the lower Ohio and Tennessee Rivers, particularly during higher water periods. However, these tows arrange in advance to pass through the locks in 108'x1200' (or smaller) configurations.

Constraint #3: The Ohio River Mainstem will remain canalized.

The study recognizes the Ohio River mainstem ecosystem is highly modified and likely to remain for the foreseeable future, due to mainstem impoundment by the Corps that began in the late 19th century and is continuing into the 21st century. Floodplain development, which encompasses extensive industrial, commercial, and residential use and infrastructure essential to transportation and community services, is based on existing pool

levels created by the system of high-lift dams begun in the mid-20th century. Returning the river to its pre-impoundment state would have profound environmental, economic and engineering implications. It is therefore unrealistic, if not impossible, to return the floodplain to predevelopment conditions.

Constraint #4: Impacts to Ohio River Floodways will be minimized.

The Federal Emergency Management Administration (FEMA) and individual states along the Ohio River have attempted to curtail construction in flood prone areas. Care will be taken in final plan design (during Preliminary Engineering and Design stage) to assure compliance with appropriate Federal and states' floodplain and floodway regulations.

Assumption #1: There will be no constraints on assessing the Ohio River Mainstem's resource needs.

This study examined and assessed the resources, ecosystems and human communities of the Ohio mainstem by assuming the perspective of each resource itself. In keeping with this unique approach, no institutional, fiscal, or temporal constraints were imposed while developing recommendations beneficial to the resources. Lack of such constraints stimulated open-ended thinking and flexibility in considering conditions over such a protracted time frame. Extending this approach as an example, the study not only examined conformance to existing programs and legislation relevant to the resources but also explored trends that may lead to new opportunities and solutions to present resource problems.

Assumption #2: Determination of Dam Maintenance is based on Results of Other Studies and Engineering Judgment.

1. Dam components were not specifically modeled using reliability analysis as a part of the ORMSS. Gates, electrical and mechanical components, and concrete components of all dams were initially considered for reliability analyses; however, as the state-of-the-art methodology for implement reliability analysis was developed under ORMSS, funding and budget issues led the team to focus on lock components. Recent dam rehabilitation studies (Emsworth, J.T. Myers) that either have been completed or are currently in process have been taken into consideration for these projects and those with similar problems. As previously described, the only Ohio River dams currently being rehabilitated are the main and back channel dams at Emsworth; however, the J.T. Myers Dam Rehab Study was completed in FY07. The investment strategy resulting from specific engineering and economic studies related to the on-going major rehabilitation at Emsworth was incorporated into analyses for the SIP, as was the projected needs at J.T. Myers based upon the latest analysis of that MR study.

2. Currently, there are no known stability issues associated with any dam piers or the fixed weirs for Ohio River dams. The original safety factors included in the design of these structures and the fact that overall condition of these structures does not change significantly with time led to the conclusion that they would remain reliable throughout the study period.

Assumption #3: No Assessments of Alternatives Involving the Removal Of Any Locks and Dam Will Be Included In This Study.

Plans to reduce the number of locks and dams below nineteen are not included in any analyses for this study. The economic, environmental, and social impacts of this type of plan would be fully considered in future site-specific studies if deemed appropriate. Deferral of consideration of this type of plan is not expected to impact the schedule of future studies developed through use of this SIP. Furthermore, addressing the potential elimination of a facility in this SIP would require case specific modification of the CEA and PEIS, which is beyond the scope and budget for this study.

Assumption #4: All Locks and Dams on Ohio River Tributaries Are Modeled as Operating at Full Capacity.

No reliability analyses were conducted at locks and dams on any of the Ohio River tributaries. These projects are modeled as operating at full capacity with no unscheduled closures due to failures of major lock components.

SECTION 7
PUBLIC INVOLVEMENT AND INTER-AGENCY COORDINATION

This section provides presents a summary of communications with various groups and public agencies throughout the Ohio River Mainstem System Study, emphasizing activities during the preparation of this System Investment Plan and Programmatic Environmental Impact Statement. These activities build upon the extensive coordination conducted during preparation of the J.T. Myers and Greenup Locks Improvements Feasibility Report (April 2000) and the Ecosystem Restoration Report (October 2000).

7.1. ENVIRONMENTAL OUTREACH

7.1.1 Summary Of Scoping Process

1. Scoping for the current phase of this study was initiated by six public meetings held in 2001. They were announced by notice in the Federal Register on June 26, 2001, with additional notification made through mailing to over 3,000 addressees on the mailing list developed during preparation of the two prior interim reports. The meeting dates and locations were: July 10, 2001, Metropolis, IL, and July 12, 2001, Evansville, IN (Louisville District); July 31, 2001, Parkersburg, WV, August 7, 2001, Portsmouth, OH, and August 6, 2001, Covington, KY (Huntington District); and August 1, 2001, Monaca, PA (Pittsburgh District). **Figure 7-1** illustrates that the six locations were distributed along the bordering states along the Ohio River. There were two primary purposes for these meetings. One was to allow input from interested agencies and individuals concerning issues that should be factored into this study. The second purpose was to satisfy part of the requirements for public scoping and coordination under NEPA for preparation of a programmatic environmental impact statement. Presentations at these meetings focused on the three key study elements – the System Investment Plan, the Cumulative Effects Assessment, and the Programmatic Environmental Impact Statement. The presentations were followed by a moderated question and answer session that typically lasted for about one hour.

2. Two sessions were held for each meeting, a daytime session with governmental agencies and an evening meeting open to the public. Forty-four people attended the six meetings with agency representatives. More than half of the participants represented federal and state resource or regulatory agencies. The remaining participants represented various public agencies or business interests. One hundred forty one people attended the six public meetings. Nearly 50 percent of the participants were interested citizens. Approximately 25 percent represented business or development interests, with

the largest representation from the shipping industry. The remaining participants included anglers, elected officials, representatives of environmental non-governmental organizations (NGOs), the media and government agencies. **Table 7-1** lists the key issues that were raised either at the public workshops or through written letters. These issues were published in the ORMSS folder on the public-accessible web page in the Louisville District -http://www.lrl.usace.army.mil/ORMSS.

FIGURE 7-1
Scoping Meeting Locations

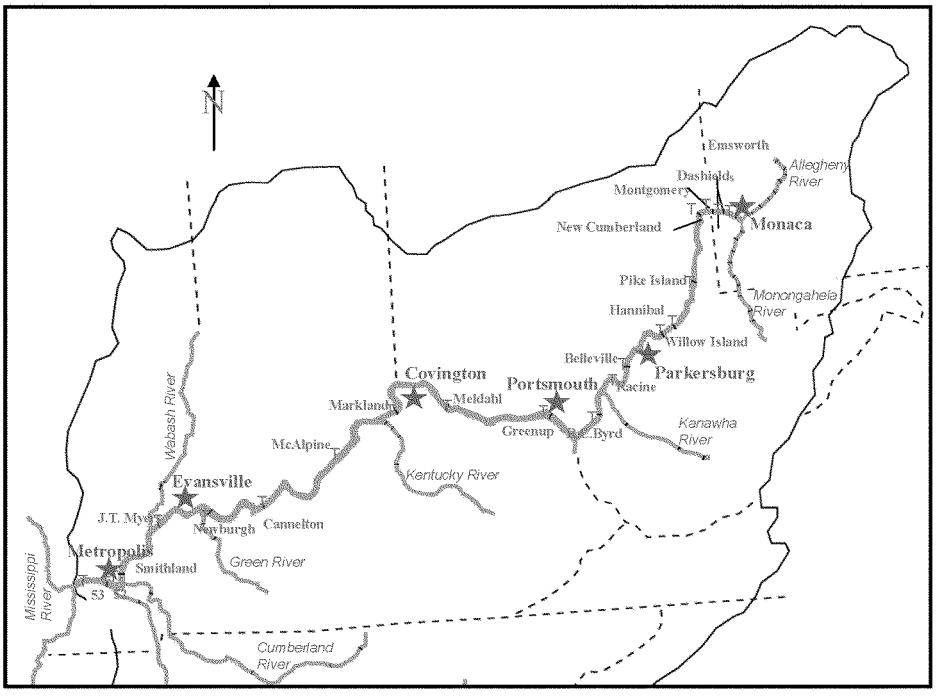


TABLE 7-1
Key Issues Raised at Scoping Meetings

Topic	Comments/Concerns
BARGE TRAFFIC	1) Loss of shoreline trees and river property caused by barge activities
	2) Reliability of barge traffic forecasts in relation to globalization and comparative costs of other modes of transportation
	3) Increased spills and accidents potentially damaging aquatic life and impairing water quality as barge traffic increases
	4) Failure of barges to stay in designated shipping lanes
	5) Changes in shipping demand as low sulfur coal reserves in the region near depletion within the next 25 years
	6) Lights from barges shining into residences and other buildings on shore
	7) Possible trash hauling by barges in the future
NAVIGATION INFRASTRUCTURE	1) Navigation improvements presently not keeping pace with traffic demands
	2) ORMSS schedule possibly lagging behind future navigation needs
	3) Scheduling and frequency of lock closures
	4) Locks' eligibility for classification as historical structures
	5) Issuance of bonds to fund navigation improvements
	6) Improvements viewed as lacking benefits except to shipping industry
INTERMODAL FACILITIES	1) Enhancement of river transportation capabilities through corresponding development/improvements of intermodal transportation facilities
	2) Need for long-range coordination with FHWA and state transportation departments
	3) Potential lack of integration of navigation with other transportation modes
LAND USE	1) Loss of significant farmland to urban development along river corridor
	2) Loss of green space and wildlife habitat with development of commercial and recreational docking/loading facilities
	3) Development of floodplains and wetlands causing increased runoff
WATER QUALITY	1) Cumulative effects of discharges to river offsetting water quality improvements
	2) Challenge to water quality presented by combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs)
	3) High levels of mercury, arsenic, chloroform and agricultural chemicals in surface water
	4) Need for more stringent discharge permitting processes or moratorium by regulatory agencies
	5) Prolonged bureaucratic procedures in obtaining discharge permits

	6) Importance of coordination between USACE and public water suppliers withdrawing from Ohio River
GROUNDWATER	1) Overall effects of navigation structures and activities on groundwater levels
	2) Protection of public groundwater supplies
SEDIMENTATION	1) Mouths of tributaries silted in, impairing fish habitat and limiting access
	2) In-stream sedimentation forming bars and causing grounding of vessels
	3) Impaired water quality and bioaccumulation of harmful substances in fish tissue from pollutants stirred up in sediments
DREDGING	1) Damage/destruction of mussel beds and fish spawning areas
	2) Use of dredge spoils to improve riparian or island habitat or for upland filling
BANK/SHORELINE INSTABILITY	1) Bank undercutting and failure caused by increased barge traffic/queuing and attendant wave action
	2) Bank erosion caused by USACE-controlled pool fluctuations
	3) Shoreline instability threatening costly restoration projects in wildlife management areas
POOL ELEVATIONS	1) Adverse effects on bridges and property from higher pool elevations
	2) Pools maintained at a higher elevation than agreed on in flowage easement contracts with riparian property owners
RECREATION/ FISHING	1) Need for more public access ramps in each pool to reduce recreational crafts' usage of locks
	2) Interest by State of Ohio in increasing river access to promote Ohio River as a vacation destination
	3) Degradation of recreational value of river caused by increasing industrialization
	4) Health and safety concerns related to increased traffic and discharges
	5) Impaired fishing caused by water level fluctuations
	6) Fishermen underrepresented in ORMSS scoping process
FISH & WILDLIFE	1) Need for fish habitat improvements, including fish passages around locks/dams
	2) USASCE role when fish kills occur
	3) Loss of wildlife corridors as shoreline develops
	4) Stress and disruption of waterfowl migratory patterns caused by barge traffic
THREATENED & ENDANGERED SPECIES	1) Need for USACE to coordinate with US Fish & Wildlife Service on these issues
	2) Potential displacement of interior least tern from Cottonwood Island
	3) Development constraints related to endangered and threatened species
EXOTIC SPECIES	Preventing distribution of exotic plants and animals as a result of

	USACE actions
CULTURAL RESOURCES	Need to adequately address the Native American Grave Protection and Repatriation Act (NAGPRA)
ENERGY	Need for possible development of hydroelectric power at dams by private concerns
TRASH	1) Increasingly becoming a problem for property owners and river users
	2) Need for stricter litter laws
AESTHETICS	Impairment of scenic value of river corridor for millions of people living in the Ohio Valley
PRIVATE PROPERTY	1) Procurement and control of land by the federal government (e.g. land acquired for OR Islands National Wildlife Refuge)
	2) Restrictions placed on property owners participating in federal programs (e.g. Conservation Reserve Program)
ORMSS	1) Possible overemphasis on transportation and river commerce
	2) Sufficiency of input from other federal agencies, including U.S. Coast Guard
	3) Sufficiency of scoping meetings notification process
	4) Procedures for getting on mailing list and receiving follow-up materials
	5) Issuance of official Record of Decision (ROD) for ORMSS
	6) Application of Ohio River Navigation Investment Model (ORNIM) to ORMSS
	7) Relationship between ORMSS and completion of Olmsted L/D
CEAs	1) Tendency for Cumulative Effects Assessments (CEAs) to emphasize negative impacts
	2) Need for ORMSS CEA to go beyond navigation structures when addressing the system's "carrying capacity"
	3) Need to learn from other CEAs
	4) Interest in including a vision for the future of the Ohio River in 2060
	5) Methods for assessing water quality in the CEA
	6) Relationship between CEA and site-specific impacts
	7) Accuracy of models used for predicting population growth, riverfront development and industrial expansion
BASELINE CONDITIONS	1) Need to define, limit and establish parameters of baseline conditions
	2) Importance of coordination with resource agencies in determining baseline conditions
	3) Need to define parameters for Reasonably Foreseeable Future Actions (RFFAs)
	4) Importance of understanding baselines for different environmental components

ECOSYSTEM RESTORATION PROGRAM	1) How, when and where the Ecosystem Restoration Program (ERP) will be funded and implemented
	2) Ability to raise 35percent local match for environmental restoration projects
	3) Potential difficulty in identifying non-federal partners
	4) Clarification of relationship between ORMSS and ERP
	5) Understanding of what constitutes ecosystem restoration

3. A summary of the meetings was issued to all attendees about three months after the meetings were concluded. Further, a composite "Scoping Comments Matrix" was compiled to summarize all of the received comments and issues identified from the meetings. The comments were grouped into categories as illustrated in **Table 7-1** (in many cases the same comment was made multiple times, and this was so noted in the matrix). The Scoping Comments Matrix is in the Environmental Appendix, CEA Report, Exhibit A. Its structure consisted of the left column comprised of the categories in **Table 7-1**, with as many rows as needed for the individual comments and issues associated with each category. Twelve columns in the matrix related to the 12 VECs, with three additional columns associated with an authorized but unfunded Ecosystem Restoration Program (ERP), the overall ORMSS, and general concerns. Each comment row was connected, as appropriate, to the relevant columns. The final column in the matrix was entitled "Action", and a brief statement was included as to the disposition of each comment relative to the CEA study. The following "actions" were typically noted:

- Comment noted (no further action needed at this time)
- Currently being addressed
- Will be addressed (later in the CEA study)
- Will be addressed for a specific VEC (later in the CEA study)
- Addressed in the (scoping) meeting
- Comment will be forwarded to the ERP team

4. An early section in each of the VE C chapters in the Environm ental Appendix included a tabulation of the pertinent dire ct and related comments. These comm ents were addressed, as appropriate, in the resp ective chapters. Further, they were used, along with other information, in the prioritization of the VEC chapters into higher and lower im portance groups. The higher im portance group includes aquatic ecological resources (water quality/sedim ent qualit y, m ussels, and fish), riparian/floodplain ecological resources, hum an health and sa fety, recreation, and transportation. The lower im portance group included chapters on air quality, socio economics, land use, and cultural resources.

7.1.2 Interagency Coordination

1. Throughout the ORMSS study, including preparation of the earlier interim feasibility studies, the environmental team maintained regular communication with resource agencies through regularly scheduled meetings with an Interagency Work Group (IWG) held at various locations along the Ohio River. **Table 7-2**, lists the locations and attendees at each of the meetings starting in April 2001, at which time the preparation of the SIP, PEIS, and CEA began in earnest. **Table 7-2** also includes eight meetings (shown by asterisk) with other professional or multi-agency groups with interests in environmental management.

TABLE 7-2. Environmental Meetings

Date(s) / Meeting/Location	Audience
October 29, 1996/Interagency Team Meeting/**Wheeling, WV**	USFWS, State Resource Agencies, EPA, NGOs
October 31, 1996/ Interagency Team Meeting/**Louisville, KY**	USFWS, State Resource Agencies, EPA, NGOs
January 23, 1997/**Cincinnati**	State Historic Preservation Officers
February 6, 1997/Interagency Team Meeting/**Columbus, OH**	USFWS, State Resource Agencies, EPA, NGOs
May 21, 1997/In-Progress Review Meeting-/**Cincinnati, OH**	USFWS, State Resource Agencies, EPA, NGOs, Navigation Industry
August 27, 1997/NAVPAT Model Explanation/**Vicksburg, MS**	USFWS, State Resource Agencies, EPA, NGOs (?)
November 13, 1997/Interagency Team Meeting/**Columbus, OH**	USFWS, State Resource Agencies, EPA, NGOs
February 24, 1998, Interagency Team Meeting/**Parkersburg, WV**	USFWS, State Resource Agencies, EPA, NGOs
April 14-15, 1998, In-Progress Review Meeting/**Pittsburgh, PA**	USFWS, State Resource Agencies, EPA, NGOs, Navigation Industry
August 7, 1998/Interagency Team Meeting/**Cincinnati, OH**	USFWS (w/directors), State Resource Agencies, EPA, NGOs
May 27-28, 1998/Interagency Team Meeting/**Louisville, KY**	USFWS, State Resource Agencies, EPA, NGOs
July 21, 1998/Interagency Team Meeting/**Huntington, WV**	USFWS, State Resource Agencies, EPA, NGOs
August 12, 1998/Scoping Meeting/**Pittsburgh, PA**	Pennsylvania Resource Agencies
August 27, 1998/Scoping Meeting/**Columbus, OH**	Ohio Resource Agencies
October 20-21, 1998/Interagency Team Meeting/**Louisville, KY**	USFWS, State Resource Agencies, EPA, NGOs
January 26-27, 1999/Interagency Team Meeting/**Parkersburg, WV**	USFWS, State Resource Agencies, EPA, NGOs
March 30-31, 1999/Interagency Team Meeting/**Ashland, KY**	USFWS, State Resource Agencies, EPA, NGOs

July 21-22, 1999/Interagency Team Meeting/**Evansville, IN**	USFWS, State Resource Agencies, EPA, NGOs
October 28-29, 1999/Interagency Team Meeting/**Cincinnati**	USFWS, State Resource Agencies, EPA, NGOs
January 19, 2000/Ecosystem Restoration Presentation/**Frankfort, KY**	Ohio River Fish Management Team
January 20-21, 2000/Interagency Team Meeting/**Frankfort, KY**	USFWS, State Resource Agencies, EPA, NGOs
January 26, 2000/Ecosystem Restoration Presentation/**Crittenden, KY**	State Resource Agencies
February 9, 2000/Recommendations for Greenup & Myers/**Greenup, KY**	Environmental Agencies, Navigation Industry & General Public
February 14, 2000/Recommendations for Greenup & Myers/**Mt. Vernon, IN**	Environmental Agencies, Navigation Industry & General Public
February 15, 2000/Study Update/**Somerset, PA**	PA Fish and Boat Commission
April 3-4, 2000/Interagency Team Meeting/**Frankfort, KY**	USFWS, State Resource Agencies, EPA, NGOs
June 13-15, 2000/Ecosystem Restoration Study Update/**Marietta, OH**	USFWS, State Resource Agencies, EPA, NGOs
July 18-19, 2000/Interagency Team Meeting/**Pittsburgh, PA**	USFWS, State Resource Agencies, EPA, NGOs
August 4, 2000/Coordination Meeting/**Cincinnati, OH**	ORSANCO
September 15, 2000/Aquatic Studies Update/**Frankfort, KY**	USFWS and Ohio River Fish Management Team
October 12, 2000/Recommendations for Ecosystem Restoration Program/**Cincinnati, OH**	Environmental Agencies, Navigation Industry & General Public
October 24-25, 2000/Interagency Team Meeting/**Crittenden, KY**	USFWS, State Resource Agencies, EPA, NGOs
November 27-29,.2000/Environmental Monitoring & Assessment/**St. Louis, MO**	EPA
January 30-31, 2001/Interagency Team Meeting/**Columbus, OH**	USFWS, State Resource Agencies, EPA, NGOs
February 6-8, 2001/Ecosystem Restoration Meeting/**Columbus, OH**	USFWS
March 14-16, 2001/Ecosystem Restoration Update/Bettendorf, IA	Mississippi River Conservation Committee
March 26, 2001/Lock Design Workshop (Environmental Considerations)/**Vicksburg, MS**	Corps of Engineers
March 31, 2001/Ecosystem Restoration Update/**California, PA**	Western Pennsylvania Conservancy
April 5, 2001/ Interagency Team Meeting/**Frankfort, KY**	USFWS, State Resource Agencies, EPA, NGOs
June 5-6, 2001/Ecosystem Restoration Meeting/**Louisville, KY**	USFWS
July 10, 2001/ORMSS Scoping Meeting/**Metropolis, IL**	Resource Agencies and General Public
July 11, 2001/Interagency Team Meeting/	USFWS, State Resource Agencies, EPA,

Paducah, KY	NGOs
July 12, 2001/ORMSS Scoping Meeting/**Evansville, IN**	Resource Agencies, Navigation Industry and General Public
July 31, 2001/ORMSS Scoping Meeting/**Parkersburg, WV**	Resource Agencies, Navigation Industry and General Public
August 1, 2001/ORMSS Scoping Meeting/**Beaver, PA**	Resource Agencies, Navigation Industry and General Public
August 6, 2001/ORMSS Scoping Meeting/**Covington, KY**	Resource Agencies, Navigation Industry and General Public
August 7, 2001/ORMSS Scoping Meeting/**Portsmouth, OH**	Resource Agencies, Navigation Industry and General Public
October 2-3, 2001/Poster Session/**Rend Lake, IL**	State DNR Directors
October 11, 2001/Poster Session/**Louisville, KY**	Ohio River Basin Consortium for Research and Education
October 17, 2001/ORMSS Presentation/**Covington, KY**	Cincinnati Propeller Club
October 25, 2001/Cumulative Effects Assessment Course/**Memphis, TN**	Corps of Engineers
November 14-15, 2001, Interagency Team Meeting Cincinnati, OH	USFWS, State Resource Agencies, EPA, NGOs
November 20, 2001, Portsmouth, OH	Shawnee Nature Club, Quarterly Meeting
December 18-19, 2001/ORMSS Presentation/**Cincinnati, OH**	ORSANCO Advisory Committee
February 1, 2002, Interagency Team Meeting Frankfort, KY	USFWS, State Resource Agencies, EPA, Non-Governmental Organizations (NGOs)
February 28-29, 2002, **MV MISSISSIPPI**	Midwest Natural Resource Leaders Group
March 19-21, 2002, **Anstedt, WV**	USFWS, Ecosystem Team
June 11, 2002/Interagency Team Meeting/Paducah, KY	USFWS, State Resource Agencies, EPA, NGOs
August 26, 2002/Green River-Ohio River Confluence/**Louisville, KY**	USFWS, Kentucky DFWR, Kentucky DOT
November 7, 2002/N. Kentucky University?	Ohio River Basin Consortium for research and Education
November 13, 2002, Interagency Team Meeting Columbus, OH	USFWS, State Resource Agencies, EPA, NGOs
November 20, 2002/Columbus, OH	TNC
Feb 5, 2003/Cincinnati, OH	Ohio River Fish Management Team
Mar 1, 2003/Cincinnati, OH	Midwest Natural Resources Leaders Group
Apr 23, 2003/Interagency Team Meeting/Cincinnati, OH	USFWS, State Resource Agencies
Jul 9, 2003/Pittsburgh, PA	PA Environmental Council
Sep 9, 2003/Interagency Team Meeting/Marietta, OH	USFWS, State Resource Agencies, EPA, NGOs
Feb. 10-11, 2004/Interagency Team	USFWS, State Resource Agencies

May 11, 2004/Interagency Team Meeting/Pittsburgh, PA	USFWS, State Resource Agencies
Aug. 18-20, 2004/Athens, Ohio	Ohio River Basin Consortium for Research & Education
Oct 19. 2004/Frankfort, KY	Interagency Team Meeting
Dec 12-15, 2004/Indianapolis, IN	Midwest Fish and Wildlife Assoc.
Oct 26-28, 2004/Huntington, WV	Ohio River Basin Consortium for Research & Education
May 16-17, 2006/Frankfort, KY	Interagency Team Meeting

2. The IWG consists of approximately 40 members representing federal and state agencies with responsibilities for environmental management, as well as several NGOs. Six members were from the U.S. Fish and Wildlife Service, with one serving as the coordinator for the USFWS group; two were from the U.S. Geological Survey; and one was from the U.S. Environmental Protection Agency. Members from NGOs include one person from the Sierra Club, one from the Ohio River Foundation, and two from The Nature Conservancy. The remaining members are from natural resources or environmental management agencies in the six states bordering the Ohio River. The IWG had two to three meetings annually with the environmental team. These one to two day joint meetings included information dissemination and updates related to the status of the CEA study, status reports on specific research projects, and working sessions on integrative topics such as impact matrices for RFFAs, and indicators and a process for analyses of environmental sustainability (AES). More specifically, the IWG fulfilled the following purposes in the CEA study:

- Aided in identifying key issues and cumulative effects that should be addressed in the CEA study.

- Assisted the Central Planning Team in delineating and prioritizing key research needs relative to environmental issues and natural resources. Examples of completed research include fish passage studies at selected locks, determination of winter habitat requirements for selected fish species, and surveys of freshwater mussel populations at various River locations. In addition, the IWG has reviewed the completed research reports.

- Participated in the completion of RFFA matrices for VECs and their subcomponents related to aquatic ecological resources, floodplain/riparian ecological resources, and threatened/endangered/protected species.

- Reviewed work plans for addressing cumulative effects on the 12 VECs and their subcomponents; in addition, reviewed the identified methods and procedures relative to "best practice tools" for the specific issues and cumulative effects to be addressed. It should be noted that "best practice tools" infer both scientific validity and cost-effectiveness relative to their application.

- Conducted systematic reviews of draft chapters and appendices for the CEA study report and the SIP/PEIS.

- Provided periodic and continuing scientific information on emerging issues; examples include the incorporation of the environmental sustainability analyses and the need to consider nonstructural measures for navigation traffic management, along with proactive repair and rehabilitation of existing locks and dams, and lock extensions.

- Participated in the planning and implementation of a coordinated and collaborative long-term strategy for environmental monitoring and adaptive environmental management for the aquatic and floodplain/riparian ecological resources within and along the Ohio River mainstem. In fact, the IWG could become part of a long-term decision-making structure and process related to enhancing the environmental sustainability of key resources.

7.2 CORPS INTERACTION WITH THE PUBLIC

1. The Corps used two primary means to regularly update the general public with progress and issues throughout development of the SIP. The URL site on the Louisville District Web Page cited above for the Scoping Meeting Comments also contained links to a general fact sheet and compilations of Frequently Asked Questions (FAQs). Two FAQ sheets were maintained, one solely relating to economic modeling and analysis issues, the other for all other types of concerns.

2. Data related to use of the URL site www.lrl.usace.army.mil/ORMSS (not available as this is being written) is available for two time periods. For the time period 14 April 2003 to 21 July 2004, the URL site averaged 9 visits per day on weekdays and 15 visits per weekend. For this time period, the web site had 4,254 visits. Out of these 4,254 visits, 2,137 visits were by unique visitors. This means that the difference between these two numbers, 2117 visitors, or roughly half, were repeat visits. The average number of visits per four-week period is 151, with an average of 76 unique visitors per four-week period. For the period of 1/1/2005 to 9/13/2005, the URL site averaged 3 visits per day on weekdays and 6 visits per weekend. For this time period, the website had 870 visits. Out of these 870 visits, 295 were by unique visitors. This means that the difference between these two numbers, 575, were repeat visitors. The average number of visits per four-week period is 62, with an average of 32 unique visitors per four-week period.

3. Other presentations directed to specific technical audiences were accomplished as described in **Table 7-3**. Comments generated were considered in technical analyses conducted for this study.

TABLE 7-3. General Meetings

Dates/Meeting/Location	Audience	ORMSS Team Presentation(s)
January 2004/Transportation Research Board/Washington, D.C.	Academic and Business Transportation Officials	ORNIM
July 16-17, 2002/ Economic and Environmental Conference, US Army Corps of Engineers/New Orleans, LA	Water resource professionals from the Corps, academia, government agencies, and various NGOs	Traffic Management
June 2-5, 2005/International Association of Impact Assessment (I.A.I.A.) Conference/Boston MA	Environmental Agencies and NGOs	Study Status, Traffic Forecast Scenarios, Environmental Sustainability, Mussels, Monitoring and Adaptive Management, and Potential Applications of Methodologies

7.3 CORPS INTERACTION WITH INDUSTRY

Coordination with industry consisted of several briefings to groups including DINAMO and the Waterways Council, Inc. that focused on progress and preliminary findings. In May 03, the Corps discussed initial forecast scenarios and implications on traffic through several locks. All meetings are listed in Table 7-4.

TABLE 7-4. Meetings and Briefings With Industry Representatives

Dates/Meeting/Location	Audience	ORMSS Presentation(s)
March 2, 2001/Inland Waterways Conference	Inland Waterways Conference Panel	
Nov. 30, 2001/Inland Waterways User Board Meeting/Fort Lauderdale, FL	Inland Waterways User Board	
Apr. 25, 2002/Inland Waterways User Board Meeting/Chattanooga, TN	Inland Waterways User Board[1]	Study Status and Commercial Traffic Forecasting
July 2002/DINAMO[1]/Ligonier, PA	DINAMO (River Transportation) Representatives	
October 31, 2002/DINAMO/Emsworth, PA	DINAMO officials	
March 11-12, 2003/Inland Waterways Conference/Cincinnati, OH	River Transportation Officials	
July 30, 2003/DINAMO/Pittsburgh, PA	DINAMO officials	Study Methodology
September 23, 2003/Houston, TX	National Waterways Conference	
January 13, 2004/Washington, DC	Waterways Council, Inc.	
March 2004/Inland Waterways User Board Meeting/	Inland Waterways User Board	
September 2, 2004/Washington, DC	Waterways Council, Inc., Great Lakes and Ohio River and Mississippi River Divisions of the Corps	
February 23-24, 2005/Tampa, FL	Waterways Council, Inc., Great Lakes and Ohio River and Mississippi River Divisions of the Corps	
March 2005/Inland Waterways User Board Meeting/	Inland Waterways User Board	

[1]Industries represented by IWUB attending meeting included Cargill Marine & Terminal, Alter Barge, Inc. MEMCO B arge Li ne, Ingram B arge C o., Pa rker To wing C o., Pea body C OALSALES C o., S haver Transportation, Holcum (US), Inc., CONSOL Energy, Inc., Kirby Corp., and American Barge Line. Also attending was Volunteer Barge & Transport, Inc.

[2]Presentations also made by representatives from HDR, Inc., Balch & Bingham, LCC, J. Simmons Group, Transportation Institute (Houston), Atlantic Intracoastal Waterways Assoc., Transportation Research Board, and House Energy & Water Development Subcommittee.

7.4 DRAFT REPORT COORDINATION/REVIEW

1. To announce the availability of the System Investment Plan, a direct mailing was made to individuals and organizations on the mailing list developed specifically for the release of the report. A post card was used for the majority of the mailing list, primarily those individuals and agencies not required to receive a copy of the report. The post cards were mailed one week prior to the release of draft report. This post card contained the following information:

- Availability of the draft SIP for review
- Web site address of report
- How to view a copy of report
- How to obtain a copy of report
- Dates and locations of public meetings
- Dates of the public review period

2. The mailing directed interested parties to the ORMSS website. Both the mailing and the website explained how to obtain paper or electronic copies of the report. The website contained Frequently Asked Questions, updated at the time to the report release to summarize the report findings, answer questions about how to obtain a copy of the report, and inform interested parties about public involvement activities. Additionally, the report itself was placed on the website, so that interested parties were able to view it. An e-mail link will be provided for those who wish to submit comments.

3. Public meetings were held at six sites, in six different states, as listed below:

- Metropolis, Illinois
- Evansville, Indiana
- Covington, Kentucky
- Huntington, West Virginia
- Marietta, Ohio
- Beaver, Pennsylvania

4. Visual aids were developed for the public meetings: maps, handouts, PowerPoint presentations, etc. Press releases announced the release of the draft report and provided summary information on the report's results.

SECTION 8
OHIO RIVER MAINSTEM WITHOUT-PROJECT CONDITION FORMULATION AND ASSESSMENT (NO ACTION ALTERNATIVE UNDER NEPA)

8.1 BACKGROUND

1. Using the traditional Corps definition of the Without-Project Condition (WOPC), the WOPC for the Ohio River Navigation System is the most likely condition expected to prevail on the Ohio River Mainstem throughout the planning horizon in absence of additional project (Congressional) authorizations. For the ORMSS, this definition has been expanded to reflect the current philosophy concerning planning for a highly uncertain future. One of the most critical determinants of the need for future investments in the Ohio River Navigation System and at the same time the most uncertain is the demand for waterway commodity movements through all Ohio River locks.

2. To address the inherent difficulties associated with predicting traffic forecasts on the Ohio River, multiple scenarios were postulated that represent a reasonable range of futures of unconstrained traffic demand. Unconstrained forecasts are necessary as a starting point so that the processing limits (that could result in delays to navigation and divert some traffic off of the river) at any of the Ohio River locks can be ascertained and solutions determined. Specifically, the goal of this approach is to define a range of reasonable alternative scenarios that ultimately describe the potential demand for transportation of major commodities transported on the Ohio River. A consequence of applying a scenario-based approach to traffic forecasting is multiple representations of the without-project condition. However, scenarios are not evaluated with respect to numerical probability or likelihood of occurrence. A single most probable without-project condition therefore is not identified. Consideration of the impacts of various scenarios will greatly enhance the decision-making process. This scenario-based approach is consistent with the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G), the procedural and analytical framework for Corps feasibility studies. The WOPC is determined for each traffic scenario and will not necessarily represent the status quo in terms of Corps operations and maintenance of the existing system in the absence of new investment. Any reasonably expected and economically justified nonstructural measure within Corps authority is assumed implemented at the appropriate time. The WOPC includes operational measures which are routinely employed during periods of congestion. These

include the use of helper boats and revised lockage policies to improve project performance and ensure the best use of the existing facilities during main chamber closures. The WOPC also includes authorized improvements that are either under construction or are pending appropriation. The most likely WOPC does not include any proactive maintenance requiring an investment decision.

3. The Ohio River project that is authorized and currently under construction, Olmsted, and those in the Preconstruction Engineering and Design stage (Greenup and Myers) are incorporated into the WOPC in accordance with the anticipated construction schedules noted in **Section 2-2**.

4. The importance of the WOPC has not changed; it still serves as the basis against which impacts of project improvements or additions requiring Congressional authorization (in any "With-Project" Condition or "WPC) are measured. The net system-wide transportation savings (benefits less costs) and impacts to the valued environmental components (VECs) due to any WPC would be compared to those values in the corresponding WOPC (i.e. based on the same set of economic and environmental forecasts). Likewise, the environmental and social measures of any With Project plan would be compared to those of the appropriate Without-Project Condition.

5. After the various traffic demand scenarios are described in subsection 8.2, maintenance, operational, low-cost structural, and ecosystem restoration measures are considered and screened. WOPC alternatives are formulated by combining these measures in a systematic way as described in subsections 8.6 for navigation and 8.8 for ecosystem sustainability. Two general navigation alternatives are evaluated as part of the WOPC. One of these alternatives is screened from the analysis. One ecosystem restoration alternative is formulated for the WOPC. The navigation alternative is evaluated as described in Section 8.7 and the ecosystem alternative is evaluated in Section 8.9.

8.2 PROJECTED TRAFFIC DEMANDS

1. Traffic demand forecasts for this study represent a comprehensive update of previous forecasts completed in the spring of 1999 for the Myers and Greenup Locks Improvements Feasibility Report. New forecasts were prepared for all commodity groups, but because of the dominance of utility steam coal on the system and the uncertainties surrounding the regulatory future, alternative scenarios were developed only for utility coal and sorbent materials (lime and limestone) used for coal desulfurization. The dominance of these commodities shipped on the Ohio River is expected to continue through the planning period although other commodities continue to represent a significant percentage of traffic in the future as well.

2. Adjustments to the 1999 forecasts were required for utility coal due to regulatory changes that occurred since then and others likely to occur in the future pertaining to the electric utility industry. The current round of adjustments to the utility coal forecasts was

necessitated by existing and likely future regulatory changes (primarily related to air emissions) affecting the electric utility industry. Coal that moves by barge to electric utilities accounts for nearly half of all traffic on the Ohio River System (ORS). This market for coal continues to receive much attention from government regulators, the Congress, and the public. Regulation and law governing coal's use overseas, and stiff competition from competing exporting countries has been responsible for the near disappearance of the steam coal export market, particularly in Europe. For the ORS, the result has been the first prolonged period of coal traffic stagnation. While other commodities and barge-served markets face uncertainty, none matches the dominance of coal or level of uncertainty regarding future use. Environmental issues are acknowledged by industry experts to be the dominant issues expected to affect future coal utilization and sourcing (i.e. result in coal switching[1]) on the part of the electric utilities. In light of this, five alternative forecast scenarios were developed, three of which directly reflect alternative legislative approaches to emissions reductions. A "broad-based" or single projection for all other traffic is also made and incorporated into each of these scenarios. Details on forecasting methodology are provided in Section 6 of the Economics Appendix.

3. Section 8.2 presents the current traffic demand forecasts for the Ohio River for the 2010-2070 planning period. In total, five alternative traffic demand forecasts for utility steam coal and the lime and limestone as previously cited were developed. These forecasts were combined with a single forecast for all other commodity traffic. For all scenarios, the arrival rate throughout the year is expected to remain relatively uniform (i.e. non-seasonal) throughout the planning horizon. Furthermore, the expected tow size distribution at each facility throughout the planning horizon is expected to be about the same as shown in **Table 4-6**.

8.2.1 Traffic Forecast Scenarios

Of the five forecasts for the shipment of utility coal demands, two were based on information obtained from utility surveys[2] regarding their plans in light of environmental regulations. These scenarios are termed the Utility-Based and Utility Based-High scenarios. The difference between these two is that the Utility Based-High scenario assumes high economic growth. The remaining three scenarios used output of Hill and Associates[3] models, based on their National Power Model and other related models. The

[1] Coal switching refers to a plant changing the sources of their coal. Different coals have different characteristics (heat, water, sulfur content). Environmental regulations may require plants to alter their coal supplies.

[2] A total of 15 companies (utilities and non-utility generators) either currently or historically using the ORS was included in the survey. Coal shipped on the ORS in 2000 by these companies totaled about 115 million tons, or 99 percent of the utility coal and 80 percent of total coal movement on the ORS that year. Each company was asked to provide estimates of generation and coal use at their plants for 2005 and 2010.

[3] Hill and Associates is a management consulting firm specializing in the coal and electric utility industries. They maintain an extensive modeling system of the electric utility industry and have done consulting work for the Department of Energy (DOE), the Environmental Protection Agency (EPA) and other clients in government and private industry. The work of Hill and Associates is consistently cited by DOE in their Annual Energy Outlook.

first of these is a continued application of existing laws, specifically the National Ambient Air Quality Standards. This scenario is referred to as the NAAQS scenario. The second Hill scenario reflects implementation of the administration's multi-emissions proposal, the Clear Skies Initiative, as an amendment to the Clean Air Act. This proposal, referred to as the Clear Skies scenario could be expected to have a fairly profound impact on the use of coal by electric utilities, largely because of the proposal's implied mercury emissions restrictions. The final Hill scenario would be implementation of the Clear Skies initiative without the severe mercury restrictions that are included under Clear Skies. This scenario is referred to as the Modified Clear Skies Scenario. All of the forecast scenarios reflect the effects of coal switching by ORS-dependent utilities to meet the requirements of existing or proposed environmental regulations. The utility-based forecasts reflect the outlook of the utilities themselves. Additional details regarding the alternative forecast scenarios are provided in **Attachment 4** of the Economics Appendix.

8.2.2 Forecast Results

This section describes the future traffic projections, with particular emphasis placed on factors impacting coal movements through Ohio River locks. Traffic for the ORS and the Ohio River Mainstem is addressed.

8.2.2.1 ORS Traffic Demands

Projected unconstrained traffic demands for the ORS under each of the five alternative forecast scenarios for the period 2010-2060 are displayed in **Table 8-1**. Traffic from 2060 to 2070 is assumed to be constant. Over the longer term, the high and low alternatives that emerge are the Utility-Based High scenario and the Clear Skies scenario. The first of these forecasts reflects the outlook of the major utility users of the ORS along with the application of the ORS utility coal model in a high economic growth framework. The second reflects implementation of the administration's Clear Skies Initiative with its expected negative impact on coal usage. In year 2020, the forecasts range between 318 million tons under the Clear Skies scenario and 350.4 million tons under the Utility-Based High scenario. By year 2060, the range is between 368.7 and 511.0 million tons for these same scenarios. Annual growth for the 2000-2060 period ranges from 0.51 percent to 1.06 percent. This is compared to annual growth over the 1970-2000 period of 1.7 percent per year.

TABLE 8-1

Actual and Projected Unconstrained ORS Traffic Demand, 1970-2060
(Million Tons)

Scenario	Actual 1970	Actual 2000	2010	2020	2030	2040	2050	2060	Annual % Growth Actual 1970-2000	Annual % Growth Projected 2000-60
Utility-Based High	163.9	271.8	312.5	350.4	393.1	439.3	463.1	511.0	1.70	1.06
Utility-Based	163.9	271.8	312.5	336.4	369.8	402.2	418.0	449.9	1.70	0.84
NAAQS	163.9	271.8	305.7	348.5	379.3	412.4	429.9	461.5	1.70	0.89
Clear Skies	163.9	271.8	268.7	318.0	331.2	344.5	356.5	368.7	1.70	0.51
Modified Clear Skies	163.9	271.8	313.1	344.4	373.5	406.1	423.0	454.0	1.70	0.86

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

8.2.2.2 Ohio River Traffic Demands

Table 8-2 shows total projected unconstrained traffic demands for the mainstem Ohio River through 2060 with traffic assumed to be constant from 2060 to 2070. Traffic demands for the mainstem show similar patterns to those for the ORS. Ohio River mainstem traffic annually accounts for about 87 percent of total system traffic throughout the forecast period. In 2020, traffic demands range between 273.6 million tons under the Clear Skies scenario and 306.1 million tons under the Utility-Based High scenario. In 2060, the range is between 322.3 and 443.2 million tons. Annual growth between 2000 and 2060 under Clear Skies is 0.5 percent and under the Utility-Based High scenario 1.03 percent. Over the 1970-2000 period, growth rates for traffic on the Ohio River mainstem were substantially higher than for the ORS overall (2.1 versus 1.7 percent per annum). For the forecast period, growth rates for the ORS are slightly higher under all scenarios, indicating that traffic demand growth for tributary streams, especially the Tennessee River, are higher than the mainstem.

TABLE 8-2

Actual and Projected Unconstrained Ohio River Mainstem Traffic Demand, 1970-2060
(Millions of Tons)

Scenario	Actual 1970	Actual 2000	2010	2020	2030	2040	2050	2060	Annual % Growth Actual 1970-2000	Annual % Growth Projected 2000-60
Utility-Based High	129.6	239.0	273.3	306.1	342.2	380.0	403.4	443.2	2.06	1.03
Utility-Based	129.6	239.0	273.3	294.9	323.2	350.8	368.0	394.7	2.06	0.84
NAAQS	129.6	239.0	267.0	302.6	327.8	355.6	373.1	399.8	2.06	0.86
Clear Skies	129.6	239.0	235.1	273.6	286.1	298.9	310.6	322.3	2.06	0.50
Modified Clear Skies	129.6	239.0	271.3	297.4	320.5	347.5	364.6	390.5	2.06	0.82

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

8.2.2.3 Lock-Level Traffic Demands

1. Unconstrained traffic demand forecasts for the Ohio River mainstem locks are displayed in **Table 8-3**, again with traffic levels assumed constant between 2060 and 2070. (Traffic forecast on the Ohio River mainstem by commodity group is provided in the **Economic Appendix**.) These lock-specific forecasts are very sensitive to environmental regulations that can affect coal sourcing for various plants, and this in turn can significantly affect the coal movements through the Ohio River facilities. Due primarily to such differences in coal sourcing, forecasts can align quite differently at the locks. For example, the high forecast at one lock might not be the high forecast at another.

2. Under most of the forecast scenarios, forecast growth rates are the highest for the lower river locks. This reflects an increased interest in Illinois Basin and Northern Illinois coals on the part of the utilities, as well as increases in the movement of western coal on the Ohio River System. Utilities are expected to include more Illinois Basin, as well as Northern Appalachian, coals in their mixes. The increasing demand for coal from these sources, which is relatively high in sulfur content but lower in cost than coals now used from the Kanawa basin, is due to the fact that scrubbers are becoming more widespread, which render the sulfur content of coals less important. Many plants have added scrubbers during major modifications to their plants and new plants have incorporated scrubbers because of the environmental regulations regarding modified and new plants. Some utilities have reached the point where their least-cost option for meeting their environmental requirements is to add scrubbers. Northern Appalachian coal always has and is expected in the future to move primarily on the middle and lower Ohio River (serving, for example, the Florida coal market). Use of this coal in the scenarios is reflected in traffic growth downstream of and including Hannibal.

TABLE 8-3

Unconstrained Projected Lock Traffic Demand (Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Emsworth:								
Utility-Based High	21.9	24.6	25.7	27.8	29.7	30.8	33.3	0.70
Utility-Based	21.9	24.6	24.8	26.1	27.5	28.3	29.8	0.51
NAAQS	21.9	22.1	30.1	32.2	34.3	36.0	38.2	0.93
Clear Skies	21.9	19.2	24.8	24.9	25.2	25.6	26.0	0.28
Modified Clear Skies	21.9	23.9	26.9	28.6	30.4	31.9	33.8	0.72
Dashields:								
Utility-Based High	22.4	25.0	26.2	28.3	30.2	31.3	33.9	0.69
Utility-Based	22.4	25.0	25.3	26.6	28.0	28.8	30.3	0.51
NAAQS	22.4	22.5	30.6	32.7	34.8	36.5	38.8	0.92
Clear Skies	22.4	19.7	25.3	25.4	25.8	26.2	26.6	0.29
Modified Clear Skies	22.4	24.4	27.4	29.1	30.9	32.4	34.4	0.72
Montgomery:								
Utility-Based High	25.2	27.3	28.5	30.8	32.9	34.1	36.9	0.63
Utility-Based	25.2	27.3	27.6	29.1	30.6	31.6	33.3	0.46
NAAQS	25.2	26.0	34.7	37.0	39.4	41.3	43.9	0.93
Clear Skies	25.2	22.2	28.3	28.5	29.1	29.6	30.2	0.30
Modified Clear Skies	25.2	27.8	31.7	33.8	35.9	37.6	39.9	0.77
New Cumberland:								
Utility-Based High	34.2	35.8	37.0	40.1	43.0	44.5	48.5	0.58
Utility-Based	34.2	35.8	35.7	37.7	39.8	41.0	43.7	0.41
NAAQS	34.2	35.9	47.2	50.4	53.5	55.8	59.3	0.92
Clear Skies	34.2	23.5	38.2	38.6	39.3	40.1	40.9	0.30
Modified Clear Skies	34.2	42.5	43.8	46.6	49.4	51.6	54.7	0.79
Pike Island:								
Utility-Based High	42.3	46.7	48.8	53.0	56.5	58.9	64.0	0.69
Utility-Based	42.3	46.7	47.3	50.1	52.8	54.8	58.3	0.54
NAAQS	42.3	47.7	58.9	63.0	66.8	69.9	74.2	0.94
Clear Skies	42.3	35.4	51.0	51.8	53.1	54.3	55.7	0.46
Modified Clear Skies	42.3	54.3	55.8	59.5	63.0	65.9	69.9	0.84
Hannibal:								
Utility-Based High	49.8	63.0	64.8	71.4	77.1	82.1	90.7	1.00
Utility-Based	49.8	63.0	62.2	66.6	71.0	74.7	79.9	0.79
NAAQS	49.8	66.8	72.6	78.3	83.8	88.8	95.0	1.08
Clear Skies	49.8	52.0	60.6	61.6	62.9	64.3	65.8	0.47
Modified Clear Skies	49.8	70.3	75.0	80.9	86.5	91.7	98.0	1.14
Willow Island:								
Utility-Based High	47.0	59.1	61.4	67.5	72.8	77.4	85.1	0.99
Utility-Based	47.0	59.1	59.0	63.1	67.2	70.6	75.5	0.79
NAAQS	47.0	63.5	69.3	74.6	79.9	84.6	90.5	1.10
Clear Skies	47.0	48.7	57.4	58.3	59.7	61.2	62.7	0.48
Modified Clear Skies	47.0	67.0	71.7	77.2	82.7	87.5	93.6	1.15

TABLE 8-3 (cont)

Unconstrained Projected Lock Traffic Demand
(Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Belleville:								
Utility-Based High	50.9	63.3	65.7	72.0	77.5	82.3	90.1	0.96
Utility-Based	50.9	63.3	63.4	67.6	71.9	75.5	80.6	0.77
NAAQS	50.9	67.7	73.7	79.1	84.6	89.5	95.6	1.05
Clear Skies	50.9	52.9	61.7	62.9	64.4	66.0	67.8	0.48
Modified Clear Skies	50.9	71.2	76.1	81.7	87.3	92.4	98.6	1.11
Racine:								
Utility-Based High	51.5	63.9	66.3	72.6	78.1	82.9	90.8	0.95
Utility-Based	51.5	63.9	64.0	68.2	72.5	76.1	81.3	0.76
NAAQS	51.5	68.3	74.3	79.8	85.2	90.1	96.3	1.05
Clear Skies	51.5	53.5	62.3	63.5	65.1	66.7	68.4	0.48
Modified Clear Skies	51.5	71.8	76.7	82.4	88.0	93.0	99.3	1.10
Byrd:								
Utility-Based High	59.1	70.7	76.4	83.7	91.1	97.7	107.0	1.00
Utility-Based	59.1	70.7	73.4	78.6	84.1	88.6	94.7	0.79
NAAQS	59.1	56.9	63.2	67.3	71.9	76.0	80.8	0.52
Clear Skies	59.1	52.7	56.4	57.9	59.9	61.8	63.9	0.13
Modified Clear Skies	59.1	56.4	65.7	70.1	74.8	79.1	84.1	0.59
Greenup:								
Utility-Based High	74.0	83.9	92.9	103.0	114.2	124.2	137.0	1.03
Utility-Based	74.0	83.9	89.0	96.7	104.6	111.3	119.9	0.81
NAAQS	74.0	64.0	71.0	76.4	82.2	87.6	93.6	0.39
Clear Skies	74.0	58.5	64.6	67.4	70.6	73.6	76.9	0.06
Modified Clear Skies	74.0	63.8	72.4	78.0	83.8	89.3	95.4	0.43
Meldahl:								
Utility-Based High	64.6	72.1	77.7	85.6	94.7	102.5	112.5	0.93
Utility-Based	64.6	72.1	75.0	81.3	87.7	93.1	99.9	0.73
NAAQS	64.6	55.6	61.8	66.4	71.1	75.8	80.9	0.37
Clear Skies	64.6	50.2	54.9	57.5	60.4	63.3	66.4	0.05
Modified Clear Skies	64.6	55.4	62.6	67.3	72.0	76.7	81.9	0.40
Markland:								
Utility-Based High	56.0	65.6	68.9	75.4	82.9	88.0	95.9	0.90
Utility-Based	56.0	65.6	67.3	72.8	78.5	82.8	88.4	0.76
NAAQS	56.0	56.9	69.7	75.3	80.9	86.0	91.7	0.82
Clear Skies	56.0	51.7	63.6	66.8	70.2	73.5	76.9	0.53
Modified Clear Skies	56.0	56.2	66.8	72.0	77.3	82.2	87.6	0.75
McAlpine:								
Utility-Based High	55.2	65.3	70.2	76.8	84.4	90.5	98.4	0.97
Utility-Based	55.2	65.3	68.6	74.4	80.4	85.2	91.2	0.84
NAAQS	55.2	68.8	82.3	89.1	96.2	103.1	110.3	1.16
Clear Skies	55.2	54.7	72.8	76.3	80.1	83.9	87.6	0.77
Modified Clear Skies	55.2	71.0	77.2	83.5	90.1	96.4	103.0	1.05

TABLE 8-3 (cont)

Unconstrained Projected Lock Traffic Demand
(Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Cannelton:								
Utility-Based High	54.1	66.1	71.7	78.6	86.7	92.8	101.2	1.05
Utility-Based	54.1	66.1	70.0	76.1	82.4	87.3	93.6	0.92
NAAQS	54.1	71.5	85.1	92.4	100.0	107.1	114.8	1.26
Clear Skies	54.1	58.0	72.8	76.5	80.5	84.2	88.2	0.82
Modified Clear Skies	54.1	74.1	80.9	87.7	94.8	101.5	108.7	1.17
Newburgh:								
Utility-Based High	63.0	75.1	83.7	93.2	103.3	110.2	121.0	1.09
Utility-Based	63.0	75.1	81.3	89.0	97.0	102.4	110.2	0.94
NAAQS	63.0	85.4	100.0	109.6	119.4	126.9	136.7	1.30
Clear Skies	63.0	69.8	83.0	86.9	91.4	95.4	99.7	0.77
Modified Clear Skies	63.0	87.7	96.3	105.5	115.0	122.1	131.5	1.23
Myers:								
Utility-Based High	72.0	85.1	97.9	110.4	125.5	131.5	145.5	1.18
Utility-Based	72.0	85.1	94.4	104.6	115.6	119.8	129.5	0.98
NAAQS	72.0	93.6	106.1	117.2	129.0	135.7	146.5	1.19
Clear Skies	72.0	77.6	88.6	93.0	98.4	103.2	107.8	0.68
Modified Clear Skies	72.0	94.3	102.0	112.6	124.0	130.3	140.7	1.12
Smithland:								
Utility-Based High	81.4	95.3	110.3	124.9	143.1	148.9	165.3	1.19
Utility-Based	81.4	95.3	105.9	118.0	130.7	134.5	145.6	0.97
NAAQS	81.4	105.8	119.9	133.2	147.4	152.0	164.6	1.18
Clear Skies	81.4	88.8	101.6	106.4	112.1	116.4	121.0	0.66
Modified Clear Skies	81.4	106.9	115.4	127.5	141.0	145.3	157.2	1.10
L/D 52: 1/								
Utility-Based High	91.8	107.5	121.2	134.7	148.9	158.4	172.4	1.06
Utility-Based	91.8	107.5	118.7	130.3	142.1	150.2	160.9	0.94
NAAQS	91.8	114.1	129.7	141.9	154.7	163.7	175.4	1.09
Clear Skies	91.8	98.5	113.1	120.6	128.5	135.1	142.1	0.73
Modified Clear Skies	91.8	116.2	127.2	138.7	151.2	159.9	171.3	1.05
L/D 53: 1/								
Utility-Based High	85.3	93.2	103.0	112.5	123.0	132.0	142.0	0.85
Utility-Based	85.3	93.2	102.1	111.1	120.5	128.5	137.1	0.79
NAAQS	85.3	92.0	102.8	108.0	117.1	124.0	132.1	0.73
Clear Skies	85.3	85.8	93.5	100.9	108.8	115.3	122.2	0.60
Modified Clear Skies	85.3	93.4	103.5	107.5	116.6	123.5	131.5	0.72

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

3. The utility-based scenarios show the lowest growth rates occurring at the uppermost locks on the Ohio, while the three scenarios developed by Hill and Associates show the lowest growth rate occurring at projects on the middle river. Generally speaking, the NAAQS, Clear Skies, and Modified Clear Skies scenarios are more pessimistic concerning the future of Central Appalachian coal than the utility-based scenarios.

8.3 MAINTENANCE MEASURES CONSIDERED

1. Maintaining the operation of any lock and dam facility requires a variety of measures ranging from routine actions performed every year to major work that could necessitate dewatering of a lock chamber to allow for repairs or replacement of various project components. Major work may involve scheduled or unanticipated (unscheduled) work.

2. Historically, lock improvement studies for ORS locks and dams have assumed unconstrained funding for major maintenance and major rehabilitation (discussed in Section 6.1) in developing the WOPC. The WOPC in navigation feasibility studies therefore typically include a mixture of non-structural and structural measures like component replacement and chamber rehabilitation not requiring congressional authorization. The Corps has authority for major rehabilitations and advanced replacements of major components (gates, valves, etc.) but recent history shows the Administration considers some component replacements and all major rehabilitation as a new start and the Administration is not currently budgeting for new starts (e.g. Markland Major Rehabilitation).

3. Therefore, for purposes of this analysis, any maintenance beyond the measures considered below is assumed to require an investment decision and is not included in the WOPC. These measures will be treated as with-project alternatives along with other structural improvements (described in Section 9).

8.3.1 Maintenance Measures Currently Implemented

Each of the measures described in this section have historically been implemented at Corps locks and dams.

8.3.1.1 Routine Operations and Maintenance

1. The routine or normal daily activities associated with operating and maintaining the projects are included in the SIP analysis. These are simply termed annual operation and maintenance (O&M) measures. Actions carried out under this category are typically handled by hired labor, but small contracts are used where feasible. Annual operating cost categories include all project site labor, overhead, equipment costs, and minor maintenance such as low-cost painting. Also included are minor contract actions such as services for grass cutting, etc. Such work does not require closures of

lock chambers, thus, there is no impact to navigation. There are normally few, if any, environmental impacts associated with this category of operating costs.

2. It is inevitable that "random minor" events that are independent of maintenance will arise that require the Corps to unexpectedly close a lock chamber for very short duration, ranging from several hours up to several days. These events involve the malfunction of equipment that can be repaired without the full repair fleet or the need to repair miscellaneous items such as floating mooring bits or wall armor. Random minor closures and associated random minor maintenance costs also reflect lock closures for periodic testing of lock equipment by either on-site or contract personnel and not the large repair fleet. Random minor closures also occur for things such as debris in lock, tow malfunctions, accidents, etc. Random minor costs are accounted for separately in economic analyses. For a detailed look as to how future levels of random minor events are projected and incorporated into the economic models, refer to **Attachment 3 of the Economics Appendix**.

8.3.1.2 Cyclical Maintenance

1. In addition to these everyday activities, all Districts perform maintenance and inspections of major lock and dam structures and operating machinery on cyclical schedules. For ORMSS purposes, this maintenance category is referred to as the Cyclical Maintenance program. This program varies for each district and project due to factors that include workload and available resources. For a more detailed look into each district's projected cyclical maintenance program, refer to Section 7 the **Engineering Appendix** . Costs are considered for maintenance of locks and dams separately.

2. Scheduled lock maintenance costs are costs related to periodic or cyclical chamber inspections that close a chamber, including any some relatively minor maintenance/repair costs. Both the inspections and significant maintenance require lock chamber closures for dewatering. The inspection-dewatering program is intended to provide an opportunity for USACE personnel to make structural assessments, note on-going problems, and make minor repairs when necessary. Inspection dewaterings typically require the chamber to be closed from 10 to 15 days. Significant maintenance dewaterings are required for major repairs to components such as miter gates, culvert valves, and/or operating machinery. Such dewaterings are typically required every 10 to 15 years depending upon the project site and condition and responsible district's maintenance program. Chambers will typically be closed from 30 to 45 days for significant maintenance depending upon the work to be accomplished and the chamber being repaired. Cyclical maintenance procedures typically do not address the long term failure probabilities (reliability) associated with fatigue/fracture and the end of useful design life and therefore it is assumed that cyclical maintenance does not have a significant affect on the overall reliability of the structures[4].

[4] This is mainly due to the fact that we are looking at failure modes that are associated with fatigue and fracture of critical members (miter gates and valves in particular)

3. Scheduled dam maintenance costs are attributed to maintenance of dam components (dam gates, operating machinery, concrete piers, etc.) This maintenance is critical to navigation but does not require a closure because the repair fleet can tie up outside the river wall keeping lock chambers open to traffic. Reliability modeling was not performed on dam components because it was not part of the project management plan (PMP). Deterministic scheduled dam maintenance costs are estimated from engineering judgment and are the same in all maintenance and improvement plans analyzed. Dam maintenance costs are included in the analysis to account for the full cost of operating the system.

8.3.1.3 Unscheduled Lock Repairs

Repair or replacement of major lock components that malfunction are performed as required and are by definition unscheduled with little or no advance notice to industry. These repairs may require extended closures of one or even both lock chambers, and are separate from the random minor closures described under routine maintenance and any cyclical maintenance. The unscheduled repairs of major lock components are in effect reactive maintenance. The major lock components included in this repair category include miter gates and machinery, filling and emptying valves and machinery, hydraulic and electric systems. These closures are considered reliability related. For additional details, see **Section 5 of the Engineering Appendix**.

8.3.2 Maintenance Measure Not Currently Implemented

One measure not currently implemented by the Corps was considered for implementation in the WOPC.

8.3.2.1 Miter Lock Gate Replacement Capability

1. The Great Lakes and Ohio River Division has begun to implement a system whereby miter gates can be repaired in a more efficient manner by using a new maintenance procedure for miter gate maintenance. This new strategy is referred to as the Miter Gate Quick Changeout System (MGQCS). The MGQCS will allow lock chamber closures for miter gate repair and maintenance to be considerably shortened in duration when compared to "traditional" methods. This system was evaluated in the June 1992 report prepared by the Louisville District (see **Table 3.1**) that recommended pursuing initiatives that would lead to the ability to change out gates quickly as miter gates are typically the main structural elements requiring maintenance during lock dewaterings.

2. Full implementation of the MGQCS has three requirements:

- A specially designed barge-mounted crane to lift the gate out of the lock.
- Gates that are modified such that they can be lifted with a crane and mitering surfaces can be adjusted quickly.

- Spare miter gates and storage piers where those gates can be stored. The spare gates would be modified in the same fashion as the existing gates.

3. At this time, the MGQCS is only partially implemented. The first item, a gatelifter crane, has been acquired. This derrick boat crane, the Henry Shreve, is based in Louisville at McAlpine L&D. The Shreve is officially a LRD asset and is scheduled based on LRD needs. It can be used in all of the 600-foot and 1200-foot locks since they are 110' wide. The required modifications to the existing miter gates have been made at some, but not all, of the Ohio River locks. All of the gates in the 600-foot lock chambers in the Louisville District (from Markland down to Smithland, to include Olmsted, listed in **Table 4-2**) have been modified. Of the 1200-foot chambers in the Louisville District, two gate leaves[5] at Newburgh, two gate leaves at Cannelton, and all eight gate leaves at Smithland remain to be modified. In the Huntington District (from Willow Island down to Meldahl, listed in **Table 4-2**), none of the gates have been modified. Current plans are for all gates at all projects below Mongtomery to be modified for lifting with the Shreve. Currently, spare gates are available only for the Olmsted project, which is currently under construction.

4. Other details of this system, including adding spare gates and storage facilities, and development of a schedule for how those gates would be rotated between main and auxiliary chambers, have not been worked out. Currently, auxiliary chamber gates that can be lifted at any Ohio River project with twin 110' wide chambers (i.e. downstream of Montgomery) can serve as a set of "spare" gates if emergency repairs are required to any of the same project's main chamber gates. A concept and design for a gate assembly/storage pier system has been developed, but a gate storage facility has been constructed only at McAlpine and Smithland. The storage facility at Smithland is to be used for both the Olmsted and Smithland projects since the spare gates can be transported short distances on the Shreve.

8.3.3 Assessment of Maintenance Measures

Routine and cyclical maintenance are necessary for continued operation and maintenance of the lock and dam system and are carried forward. Unscheduled repairs of component failures will also be required in a timely fashion to keep the system operating and is also carried forward. Additional implementation of the MGQCS by obtaining spare gates is also considered an investment and dropped from consideration for the same reasons as proactive maintenance. However, all gates below EDM are assumed to be modified for lifting with the Shreve by the beginning of the analysis period (2010), which will reduce times to make gate repairs somewhat, and this capability will be reflected in economic analyses. **Table 8-4** summarizes the assessment of maintenance measures.

[5] There are four gate sections, or leaves, per chamber at all locks, two each on the upper and lower end. All dual chambers have eight gate leaves.

TABLE 8.4
Maintenance Measures Carried Forward and Dropped From Consideration in WOPC

Summary of Maintenance Measures Carried Forward in WOPC:
Routine Maintenance
Cyclical Lock and Dam Maintenance
Unscheduled Repairs-
Maintenance Measures Dropped From Consideration in WOPC
Full Implementation Miter Gate Quick Changeout System Lock Gate Replacement
Proactive Maintenance - Scheduled Component Replacements
Major Rehabilitation

8.3.4 Cost Estimation for Reactive Maintenance Measures Carried Forward

1. Pertinent considerations for future implementation costs for the three maintenance measures retained in the WOPC are discussed below. Additional details are provided in the **Engineering Appendix**.

2. Future levels of routine maintenance and cyclical maintenance in each District are based on current practices and policies. Routine maintenance for all facilities also includes the day-to-day costs to operate the locks and dams. Annual routine maintenance costs were developed by tracking recent (1999-2003) 5-year operational costs and inflating them to current cost levels.

3. Costs and durations of any lock closures for unscheduled component repairs or replacement were determined for each site and based on engineering judgment or past experience where possible. The **Engineering Appendix** contains additional details on these costs.

8.4 OPERATIONAL EFFICIENCY AND LOW-COST STRUCTURAL MEASURES CONSIDERED

1. As previously noted, the periods of heaviest delays currently experienced at all Ohio River locks occur when the main chamber is closed for an extended period of more than about 10 days. Average delays during normal operations are typically on the order of a tenth of the average delays during significant main chamber closures. Therefore, the Corps and industry take special measures during main chamber closure events to reduce these delays, and the associated costs. These measures are described below. Of course, if delays during normal operations ever approach these delays, they could also be applied during normal operations. Currently, special operational measures during normal

operations are rarely used at Ohio River locks. On-going activities carried out by the Corps are funded entirely with Federal O&M funds, on-going activities by industry are privately funded.

2. The discussion below first addresses measures currently taken, and then additional measures that could be initiated are described and evaluated. These measures either increase vessel throughput capacity ("supply side") or seek to affect shipper behavior ("demand side"). (See *Litman, Todd, "Why Manage Transportation Demand?" TDM Encyclopedia, Victoria Transport Policy Institute, updated November 22, 2002, pp. 3 – 4.*) Additional details on these measures are provided in **Attachment 5 Traffic Management Analysis** to the Economics Appendix. See **Table 8-5** in section 8.4.3 for a summary of measures that are carried forward in the analysis.

8.4.1 Operational and Low-Cost Structural Measures Currently Implemented

The measures described in this section have been implemented for many years at Corps locks and dams.

8.4.1.1 N-up/N-down Lockage Policy

This strategy involves locking a given number (N) of tows in the same direction, then allowing the same number to proceed in the opposite direction. It takes advantage of the efficiency of proceeding with several successive "turnback"-style lockages rather than running tows through in alternate directions when queued on either side of the lock. Use of this strategy has been proven to lower delays over a "first-come-first-served" policy at virtually zero cost. This is a supply-side measure.

8.4.1.2 Helper Boats: Industry Self-Help

The use of helper boats by industry complements the N-up and N-down lockage policy. Helper boat operations are a collaborative effort between industry and the Corps. Due to traffic levels and fleet size, industry implements a helper boat policy any time a main chamber is closed on the Ohio. Industry helper boat operation significantly reduces lockage times for multi-cut lockages and typically works as follows: the last towboat to arrive at a congested project in the direction opposite of an on-going lockage operation will disconnect from its barges and move up to the lock, where it serves as a helper boat by assisting the tow locking through the project by extracting un-powered cuts of barges from the lock chamber. It will then move the barges for re-fleeting so that reconstruction of the tow does not interfere with lockage operations. Refleeting can occur at the locks on walls upstream or downstream of the lock gates, at mooring facilities or at private docks depending upon the situation. Helper boat operations are provided to each tow until all barges have moved through the lock. To be effective, the policy requires tows queued in both directions above and below the project. This is another supply-side measure that enhances capacity during a closure.

8.4.1.3 Advanced Notice of Main Chamber Closures

1. Two years before a scheduled closure, the Corps will send a notice to waterway users announcing its intent to close a lock and the expected date of closure. The notice will also include the expected delays during the closure, expressed as significant or minor, and the lockage policies that may be put into affect. Then, about six months before the scheduled closure, the Corps District and the towing companies will meet to finalize procedures for operating during the closure. A major consideration in the decision is the expected level of delays during the closure, which is estimated based on past levels of delays and current traffic levels compared to past traffic levels. If low levels of delay are expected, then the selected policy will likely be to continue to lock according to the order of arrival. However, even with low expected level of delays, special accommodations will be required because the auxiliary chambers are typically one-fourth to one-half the size of the main chambers. If major delays are expected, the announcement will also state that tows have priority in lockage over recreational craft. This is a demand-side measure as it provides industry information to better manage their vessels during a scheduled closure.

2. Other measures by the Corps intended to increase efficiencies and reduce delays during main chamber closures include prioritizing commercial over recreational lockages, which reduces the demand by recreational boaters during those periods of heavy congestion, and making available lockage reports on the Corps web page. Information contained in lockage reports, which is updated every few hours, includes the number of tows waiting in queue and river flow conditions at each facility. Coordination with industry is also conducted on a regular basis, not just during those times prior to an extended main chamber closure. These low-cost measures have proven useful and are accepted by the navigation industry and recreational boating public.

8.4.1.4 Tow Haulage

1. Tow haulage systems are relatively low-cost pieces of equipment that can be used to expedite the two-cut lockage process when there are no other towboats to pull the unpowered cut out of the chamber. Such units are not necessary at any 1200' long lock as double cuts through those chambers are not permitted. There are two principal types of tow haulage systems: permanent and portable. Permanent units consist of rail tracks located directly alongside the chamber on top of the walls and a moveable tie-down unit that moves on the rails. The unpowered barges are tied to the moveable tie-down unit by a cable, and the unit moves along the rails to pull the barges out of the chamber. Portable systems consist of two winches that are anchored atop the upstream and downstream guidewalls. The winches "crank" the cable, pulling the barges out of the chamber. The second set of barges, which are powered by a towboat, can then enter and lock through the chamber. Upon completion of the second lockage, the first and second cuts are reconnected along the guidewall.

2. The only permanent tow haulage systems on the Ohio River are installed at the 600' main chambers at Emsworth, Dashields, and Montgomery. Double lockages

through these main chambers are a common occurrence even during normal times. During the period 1998-2002, double lockages constituted between 16 and 22 percent of all commercial lockages at each of these projects. Installation of tow haulage units at locks less than 1200' in length are considered in the WOPC.

8.4.1.5 Mooring Cells

Mooring cells are structures that provide vessels a place to tie off while waiting for their turn to lock through. Without such facilities, the towboats must either push into the riverbank, which can cause erosion and damage to the shoreline vegetation, or wait out in the currents of the river, which wastes fuel. As noted in Section 6.5.3, mooring cells have been constructed by the Corps in upstream and downstream of most projects with the exception of Belleville, Racine, Greenup (a mooring cell was authorized as part of the auxiliary lock extension), Meldahl, McAlpine, and Smithland locks and dams. Adding mooring cells at these projects is considered in the WOPC.

8.4.1.6 Industry Adjustments during Main Chamber Closures

1. The objective of the towing industry during main chamber closures is to supply their customers to as near normal cycles of delivery as possible. They will try to accomplish this by pre- and post-closure shipping to build and/or replenish stockpiles, shipping via other routings for all or part of the trip, making deliveries from alternative sources, and rearranging their shipping plans to minimize trips through the projects.

2. At all times, shippers attempt to minimize the time they are pushing empty barges by arranging shipments in both directions. Their success depends on the demand for different types of commodities in the different origin and destination regions. If all movements were one-way with no backhauls, then the percent of loaded barges and empty barges through a project would each be 50 percent. The statistics on percent loaded through the projects show that, in general, the percent of loaded barges is significantly higher than 50 percent, which indicates a significant number of backhauls. The percent loaded is highest at the projects along the lower river, where the opportunities for backhauls are greater than on the upper river, where one-way coal traffic is more dominant. However during closures, the shippers on the upper river make temporary arrangements amongst themselves to maximize the throughput of the project in terms of tonnage since they are limited in terms of barges.

3. Towing companies also attempt to reduce the number of trips through projects where delays are significant. In some cases, they will employ their equipment in assembling barges above and below the congestion point so that they are prepared to get back onto their delivery schedules as quickly as possible once the main chamber is reopened. Arrival frequencies during extended closures have been observed to be less than during normal operations even without adjustments by industry due to limits on the numbers of tows and barges. The greatest reductions in tow arrival rates are at locks that are both near major ports and have significant delays during closures. These projects are the three upper projects near Pittsburgh and the mid river projects near Huntington.

8.4.1.7 Miscellaneous Measures

The Corps and industry maintain flexibility in dealing with delay situations, and often test new measures to try to decrease processing times. For example, the downstream approach area at Dashields was shortened during a recent main chamber closure by placing an anchored barge midway in the official approach area to serve as a temporary mooring area. The purpose was to reduce the time required for tows to approach the lock. Another test was a two-stage closure at Montgomery with about 5 days between the closures to clear the queues. During the first stage, work that required only a lowered water level was performed. Once this was completed, the chamber was refilled and opened for use. After the queue was cleared, the chamber was closed and de-watered to work on the gates and sills. Thus, instead of one continuous 26-day closure, there were two closures with the first lasting 8 days and the second 18 days. This was successful in clearing the queue and thereby reducing the overall level of delays experienced during the closure.

8.4.2 Operational Efficiency and Low-Cost Structural Measures Not Currently Implemented

1. Price-related traffic demand management measures are not currently used on the mainstem. Examples in this category considered in **Attachment 5 Traffic Management Analysis** to the **Economics Appendix** include scheduling of shipments (entire trips) or specific lockages, and a vehicle tracking system. Preliminary results described in that attachment indicate great uncertainty regarding the effectiveness of traffic management schemes. This is an area that requires a research effort beyond the scope of this study.

2. An example of a low-cost structural measure is extensions of the guidewalls, guardwalls, or middle wall at any project. Extensions to these walls have the potential of reducing interference between tows that are concurrently using the main and auxiliary chambers of any project. The interference reduction has the potential to more efficiently pass traffic when traffic reaches the level where both chambers are highly utilized.

8.4.3 Assessment of Operational and Low-Cost Structural Measures

Due to their proven effectiveness, all operational and low-cost structural measures currently implemented by the Corps and the towing and shipping industries will be carried forward and implemented in the Reactive Maintenance alternative for all traffic scenarios. These include the N-up/N-down lockage policy, the use of helper boats by industry, coordination with industry, permanent tow haulage units currently installed and portable units, rescheduling by industry during main chamber closures, existing mooring cells, and the miscellaneous measures described above in subsection 8.4.1. The use of helper-boats by industry effectively maximizes the capacity of the small 56'x 360' auxiliaries on the upper Ohio and at the 110'x 600' auxiliaries elsewhere. These practices, along with limiting tow sizes to five cuts during Main chamber closures on the

upper Ohio, are reflected in lock capacities reported in **Table 6-1**. Annual throughput, or capacity, is unaffected, but average delay per tow is lower than it would be otherwise.

Guide and Guard Wall Extensions

Guide and guard wall extensions are not expected to provide the capacity expansion necessary to handle future traffic volumes nor will they reduce delays when the main chamber is closed for maintenance (when interference between chambers is not a problem). Wall extensions do not meet current and future needs, so they were not carried forward into the economic modeling of the WOPC. However, such features will be considered as part of lock modernization alternatives for the WPC.

Additional Tow Haulage Units

Additional permanent tow-haulage units are not considered necessary at any of the other locks that are less than 1200' long. At the 600' auxiliaries, such units would have their greatest need during closures of the main chambers. However, during those times, industry self-help is a much better measure to pull unpowered cuts from the auxiliary chambers as that process is faster than tow haulage and queues quickly develop, thereby providing a steady supply of helper boats. They are not considered appropriate at the 360'x56' auxiliaries at Emsworth, Dashields, and Montgomery as those chambers can only lock one barge at a time and often times (during main chamber closures) tows require more then two cuts. Portable units are considered sufficient at these other small locks.

Additional Mooring Cells

Preliminary evaluations cited in the Myers and Greenup Locks Improvements – Interim Feasibility Report concluded that there is no potential for economic benefit from adding mooring cells at any lock and dam. This measure is dropped from consideration for navigation improvements. However, this measure may be appropriate from an environmental perspective and was considered as a feature of the without-project condition

Table 8-5 summarizes the assessment of operational and low cost structural measures.

8.4.4 Cost Estimation for Reactive Maintenance Operational and Low-Cost Structural Measures Carried Forward

Special lockage policies (n-up/n-down) and advanced notice of main chamber closures are implemented at negligible cost by the Corps. The additional transportation costs to industry due to delays during main chamber closures are based on hourly rates for tow boats and crew. Costs of additional or temporary mooring cells would likely be based on historic construction costs.

TABLE 8.5
Operational and Low Cost Structural Measures Carried Forward and Dropped From Consideration in WOPC

Operational and Low-Cost Structural Measures Carried Forward:	
Operational	Low Cost Structural
N-up/N-Down Lockage Policy	Existing Tow Haulage
Advanced Notice of Main Chamber Closures	Mooring Cells
Adjustment of Shipment Schedules by Industry	Temporary Mooring Facilities During Main Chamber Closures
Industry Self Help	
Operational and Low-Cost Structural Measures Dropped From Analysis	
Operational	Low Cost Structural
Traffic Scheduling	Guide/Guard Wall Extensions
Additional Mooring (for navigation)	Additional tow haulage units

8.5 ECOSYSTEM MEASURES

As introduced in 6.5, the Corps and several other agencies have existing authorities to affect ecosystem sustainability on the Ohio River. **Table 6-5** lists opportunities for enhancing ecosystem sustainability that were identified during the study in consultation with Ohio River resource experts. This list of opportunities is carried over to **Table 8-6** and matched with existing authorities currently in place within the Corps and other agencies. A comprehensive list of authorities of other agencies is discussed later in section 8.5.4, which elaborates on that topic and explains in more detail what those authorities allow.

TABLE 8-6
Existing Ecosystem Authorities

Opportunities for Enhancing Ecosystem Sustainability[1]	Corps Continuing Authorities					Ohio River Ecosystem Restoration Program	Navigation Stewardship[2]	Existing Project Authorities	Corps as First Responders at Locks and Dams	Other Agencies and NGO's
	Section 204	Section 206	Section 1135	Section 216	Section 312					
Enhance fish passage around or through dams		x		x		x	x			
Dismantle federal tributary dams										
Dismantle non-federal tributary dams		x								
Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats			x							
Allow more natural flows to mimic natural regimes including seasonal and extreme floods and droughts	x		x	x		x		x		
Restore unique mainstem habitats such as canebrakes, river bluffs and mussel beds	x		x	x		x		x		
Protect tailwaters and provide structures to serve as refugia for fish	x	x	x	x		x		x		
Create spawning shoals and other in-stream features to enhance habitat diversity in pools	x	x	x	x		x		x		
Identify and expand areas of submerged and emergent aquatic vegetation	x	x	x	x		x		x		
Protect and manage mussel populations and their habitat on a site-specific basis	x									x

TABLE 8-6
Existing Ecosystem Authorities

Opportunities for Enhancing Ecosystem Sustainability[1]	Corps Continuing Authorities					Ohio River Ecosystem Restoration Program	Navigation Stewardship[2]	Existing Project Authorities	Corps as First Responders at Locks and Dams	Other Agencies and NGO's
	Section 204	Section 206	Section 1135	Section 216	Section 312					
Mark critical locations to prevent mooring near mussel beds or special shoreline areas									x	x
Mark shallow mussel beds to reduce direct impacts of tow traffic										x
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources	x	x	x	x		x				x
Protect existing aquatic habitats, restore lost habitats and diminished resources	x	x	x	x	x x					x
Reintroduce native fauna and expand the range and populations of native fauna from reduced levels	x		x			x		x		x
Control exotics, including minimization of existing populations and prevention of new introductions	x	x	x	x		x				x
Reduce bacterial contamination from combined sewer overflows										x
Address point and non-point sources affecting aquatic nutrient balance		x	x					x		x
Minimize catastrophic contamination events through reduction of spills, accidents, and improvement of spill response procedures								x	x	X

TABLE 8-6
Existing Ecosystem Authorities

Opportunities for Enhancing Ecosystem Sustainability[1]	Corps Continuing Authorities					Ohio River Ecosystem Restoration Program	Navigation Stewardship[2]	Existing Project Authorities	Corps as First Responders at Locks and Dams	Other Agencies and NGO's
	Section 204	Section 206	Section 1135	Section 216	Section 312					
Continue remediation of CERCLA, brownfields, and other contaminated sites	x				x					X
Reconnect and restore floodplains on the mainstem and tributaries		x	x			X[3]				
Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries		x	x			X[3]		x		
Maintain or restore tributary deltas and connections between rivers and embayments		x				x				
Reforest lower reaches of tributaries to reduce siltation into embayments and mainstem		x				X[3]				
Restore wetlands in upper ends of tributary embayments to reduce siltation and create fish and wildlife habitat		x								X
Conduct economic evaluation of watershed functions and benefits							x			X

[1] See Table 6.5 and Section 6.4.2

[2] Discussion of the Navigation Stewardship Program can be found in 6.5.1

[3] Modifications to the existing Ecosystem Restoration Program may include changes in geographic scope and/or definition of project sponsor.

8.5.1 Existing Corps Authorities and Regulatory Responsibilities

1. In recent decades, specific provisions of the Water Resources Development Acts and Flood Control Acts created authorities and opportunities for the Corps to enhance environmental sustainability. Four important existing authorities are:

Sec. 204 (Water Resources Development Act of 1992 - WRDA) Beneficial Use of Dredged Materials -- Authorizes "projects for the protection, restoration, and creation of aquatic and ecologically related habitats, including wetlands, in connection with dredging for construction, operation, or maintenance by the Secretary of an authorized navigation project."

Sec. 206 (WRDA - 1996) Aquatic Ecosystem Restoration --Authorizes "development of aquatic ecosystem restoration and protection projects that improve the quality of the environment, are in the public interest, and are cost effective."

Sec. 1135 (WRDA – 1986, as amended) Project Modifications for Improvement of Environment – "Provides authority to review and modify the structures and operations of water resources projects constructed by the Corps for the purpose of improving the quality of the environment when it is determined that such modifications are feasible, consistent with the authorized project purposes, and will improve the quality of the environment in the public interest. If it is determined that a Corps water resources project has contributed to the degradation of the environment, restoration measures may be implemented at the project site or at other locations that have been affected by the construction or operation of the project, if such measures do not conflict with the authorized project purposes."

Sec. 216 (Flood Control Act- 1970) – Authorizes "investigations for modification of completed projects or their operation when found advisable due to significantly changed physical or economic conditions and for improving the quality of the environment in the overall public interest. Initial appraisal reports are prepared under 216 using operations and maintenance (O&M) funds. The cost of preparing the initial appraisal report is limited to $20,000. Results from this report can be used to support initiation of a reconnaissance study through normal budgetary process. Following the initial appraisal, the 216 study process is of the same as a normal General Investigations study. A feasibility study under Section 216 authority would be appropriate for large scale ecosystem restoration projects linked to existing Civil Works projects, but whose costs would be too large for Section 1135, Section 206, or Section 204 authorities."

2. Although many sustainability improvements can be attained through existing authorities, none (alone or in combination) provides a comprehensive approach for maintaining and improving a complex and extensive ecosystem such as the Ohio River corridor. As ORMSS got underway, a broader authorization, designated specifically for the Ohio River, was sought to establish an overarching program for its ecosystem that

would allow restoration and protection of integral ecosystem components not necessarily included under existing program authorities.

3. To address ecosystem sustainability needs, integrate existing authorities, and explore other possibilities, ORMSS undertook development of the **Ohio River Ecosystem Restoration Program (ERP)**, described in more detail in the CEA in the Environmental Appendix. The purpose of an Ohio River ERP is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. Although this program was authorized in WRDA 2000, the program has not been funded to date and is now a candidate for de-authorization. Ecosystem restoration efforts would involve a comprehensive examination of problems contributing to system degradation, and the development of alternative means for their solution. The program would be initiated and monitored by a partnership of Federal and state resource agencies and regional environmental interest groups. If implemented, projects under the ERP would aid in reestablishing many physical and dynamic processes necessary to more closely approach a natural, self-regulating ecosystem.

4. The Detailed Project Report for the Ohio River ERP was produced in 2000 and identified more than 250 potential environmental restoration projects to enhance sustainability of instream habitat, islands, wetlands, bottomland hardwood forests, and other shoreline/riparian habitat. It is important to note, however, that a Program Implementation Plan (PIP) must be prepared as a first step in initiating the program. This plan would develop details of how the program would operate and how projects would be identified, developed, and approved. The PIP would help ensure a comprehensive approach to Ohio River restoration, as opposed to a piecemeal approach of seeking approval of individual environmental projects. For each project carried forward under the program a feasibility study with appropriate analysis under the National Environmental Policy Act (NEPA) would be conducted. Other requirements, including cost-sharing (65% Federal/35% non-federal), are requirements of this program.

5. Congress has also given the Corps of Engineers the authority to regulate certain programs that have sustainability implications on or along the waterway. The most relevant authorities consist of issuing Sections 10 and 404 permits that affect navigability on the river and the filling of the waters of the United States. Since both of these permit authorities require compliance with NEPA, impacts on the environment and cumulative effects to aquatic and riparian resources must be considered before permits can be issued.

6. The Ohio River Basin Comprehensive Study would provide for a complete watershed assessment of the Ohio River Basin. The basic authority for the Comprehensive Study is contained in the resolution adopted by the Committee on Public Works of the United States Senate dated 16 May 1955. The Study would provide an opportunity to re-evaluate existing multipurpose water resources projects in the Ohio River basin (mainstem and tributaries) for primary and other allied purposes, to include ecosystem restoration.

7. Finally, the Corps, like all other Federal agencies, is required to comply with provisions of NEPA under 40 CFR 1500-1508 when seeking authorization for new projects, issuing permits, performing operation and maintenance of existing projects, or for any other decision-making by the agency. To comply, impacts to the environment must be assessed and the interested public must have opportunity to comment on proposed actions prior to commencement of work. If significant impacts are expected to occur, an Environmental Impact Statement must be prepared, and a mitigation plan must be developed, justified, and implemented to avoid, minimize, or compensate for the impacts.

8.5.2 Sustainability Focus for Mitigation and Design

8.5.2.1 Mitigation

1. As background for the ORMSS study, a comprehensive investigation was conducted to determine mitigation opportunities and authorities available to the Corps. While potential measures identified in mitigation plans are typically focused on replacement-in-kind for anticipated adverse effects of planned projects, such plans can include measures directed toward enhancing the environmental sustainability of potentially affected resources and ecosystems. Such measures could be perceived as "sustainability-focused mitigation measures." To illustrate, the ORMSS study has considered the impacts of past, present, and future actions, along with the impacts of the proposed SIP. Consideration of the impacts of historical actions of the Corps on the environment of the Ohio River Mainstem, along with the historical actions of others, suggests the need to consider potential sustainability-focused restoration of earlier damages to the resources and ecosystems. Further, since future actions by the Corps and others have been addressed in the CEA study; it is appropriate, and required by Corps policy, that mitigation be incorporated into future proposed actions by the Corps. Further, such mitigation could also be focused on enhancing environmental sustainability. Accordingly, opportunities for enhanced sustainability exist for future site-specific navigation projects involving major maintenance and/or rehabilitation, infrastructure replacements, and lock modernizations.

2. The relationship between mitigation and ecosystem restoration and protection is described in Section 19-21 (g) of Chapter 19 of Engineering Pamphlet (EP) 1165-2-1 (Digest of Water Resources Policies and Authorities) as follows:

> Mitigation deals, in part, with the concept of ecosystem restoration and protection by its recognition of the importance of certain features of the ecosystem. Mitigation addresses these ecosystem features by attempting to eliminate and/or lessen the impact of our water resource activities upon these features. Restoration and protection activities, on the other hand, will often utilize the same techniques as used in mitigation; however, the purpose of our activities will be to restore some ecological condition that has been degraded, either by our activities or those of others. Consequently, the procedures used to justify our activities, whether they are for mitigation or restoration purposes, will typically be the same. The

only distinguishable difference between mitigation and restoration activities is when they are applied.

3. Based on the above relationship, it can be concluded that mitigation is typically applied in anticipation of the adverse impacts of a Corps project or activity, while ecosystem restoration is done to repair the environment from experienced stresses, whether such stresses are due to Corps projects or actions, or by others, or combinations thereof. Finally, it can be observed that the Corps' Planning Guidance Notebook (PGN) and the Digest of Water Resources Policies and Authorities infer the need for consideration of mitigation measures across time; i.e., both measures to lessen past damages and restore degraded ecological conditions, as well as measures to avoid, minimize, and/or compensate for anticipated undesirable effects. Such measures can also include a sustainability focus.

4. The policy basis for sustainability-focused mitigation can be found in the earlier-described Environmental Operating Principle (EOP) # 1 – strive to achieve environmental sustainability. This principle can be applied to ecosystem restoration via recognition that certain natural resources, ecosystems, or species are stressed and are continuing to deteriorate relative to their sustainability. For new projects or actions, sustainability considerations could be used as the basis for identifying avoidance, minimization, or other means for enhanced mitigation, and inclusion of appropriate mitigation features in project design, construction, and operation and maintenance. This EOP, along with the other six, have now been incorporated in both an Engineering Circular (EC 1105-2-404; in May, 2003), and an Engineer Regulation (ER 200-1-5; in October, 2003).

5. Current statutory authorities support the concepts of sustainability-focused mitigation, as do specific Corps policies and regulations associated with ecosystem restoration, existing and new projects, and water quality management and streambank erosion. For example, the current statutory authorities for ecosystem restoration and mitigation for Corps plans, programs, and projects are contained in selected sections of four WRDAs (Sections 904, 906, 907, and 1135 of WRDA 1986, Sections 306 and 307 of WRDA 1990, Section 204 of WRDA 1992, and Sections 206 and 207 of WRDA 1996). Commonly used words in these sections include "protection" and "restoration", with the former typically denoting future mitigation, and the latter restoration of previous damages. Mitigation of Corps contributions to historical degradation of natural and environmental resources is specifically included in some of the above sections. Navigation-specific statutory authority related to lock and dam replacement is currently based on Section 205 of WRDA 1992 (funding of major rehabilitation modifications to enhance operating efficiency beyond the original project design). Correction of shoreline damages resulting from existing Federal navigation projects is addressed in Section 111 of the Rivers and Harbor Act of 1968 (PL90-483), as amended by Section 940 of WRDA 1986. Such corrections are specific examples of mitigation for one type of environmental effect of navigation projects; i.e., shoreline erosion and damage.

6. A related major law that is intertwined with water resources planning is the Fish and Wildlife Coordination Act (FWCA) of 1958. This law emphasizes that fish and wildlife resources are to be conserved in the planning and implementation of water resources development projects. Several sections of the FWCA incorporate provisions whereby enhanced mitigation could be included in new or modified projects. Another important feature of the FWCA is the requirement that active consultation and coordination occurs between the Corps and the USFWS and/or the NMFS.

7. Stated policies regarding the ecosystem restoration mission of the Corps are found in ER 1105-2-100 (PGN), ER 1165-2-501 (Civil Works ecosystem restoration), and EP 1165-2-502 (ecosystem restoration – supporting policy information). Specific authorities for ecosystem restoration are divided into three categories. First, Congressionally authorized studies and provisions in existing laws can be used. One example of a law in the first category is Section 216 of the 1970 River and Harbor and Flood Control Act; Section 216 is mainly useful for large-scale ecosystem restoration at completed projects. The second category encompasses programmatic authorities, including Section 1135 of WRDA 1986, as amended (project modifications for improvement of the environment); Section 206 of WRDA 1996 (aquatic ecosystem restoration); Section 204 of WRDA 1992, as amended, and Section 207 of WRDA 1996 (beneficial uses of dredged material); and Section 312 of WRDA 1990, as amended (environmental dredging). The third category involves the use of existing operation and maintenance authorities for specific projects. Two common themes arise from the three categories of ecosystem restoration authorities. First, cost sharing is typically required for the design and construction of ecosystem restoration projects. Second, such projects must be environmentally and economically justified via the application of a Cost Effectiveness/Incremental Cost Analysis procedure applied to the anticipated environmental benefits and associated costs of various measures comprising the restoration action. Further, it was determined that the Corps can engage in the planning and implementation of ecosystem restoration projects where previous Corps projects or actions are the sole contributor to degraded resources, or where they are partial contributors along with projects and actions by other governmental agencies and private developments. Finally, in certain circumstances, ecosystem restoration planning and implementation of a project can be accomplished when the entire existing degradation is a result of actions by others.

8. The Digest of Water Resources Policies and Authorities (EP 1165-2-1) includes information on mitigation planning requirements for new projects resulting from the discharge of dredged or fill material as addressed under the auspices of the Clean Water Act, and new project reports prepared under the auspices of Section 906 of WRDA 1986 and the FWCA. Further, mitigation requirements resulting from jeopardy and adverse modification opinions under the Endangered Species Act are reflected in the development of reasonable and prudent measures. Regarding existing projects and mitigation of experienced negative impacts, Section 216 of the River and Harbor and Flood Control Act of 1970 can be used to study the situation and develop appropriate measures.

9. Mitigation measures, per se, for both new and existing projects must be environmentally justified based on the potential loss of significant fish and wildlife resources, and economically justified by the consideration of the cost effectiveness of various mitigation alternatives. A key issue to note is the need for careful planning and evaluation of a variety of mitigation measures, both singly and in combination, in the development of a justified mitigation project. Further, due to the requirements of the FWCA, the policies and recommendations of the USFWS are important relative to enhanced mitigation planning. Coordination by the Corps with the USFWS and the NMFS, as appropriate, is a central feature of the requirements of the FWCA.

10. ER 1110-2-8154 addresses water quality and environmental management for Corps projects. As such, it is a uniquely important Corps regulation related to enhanced mitigation. The national policy of the Federal government regarding water quality management is articulated along with the Corps' companion policy, specific commitments, and three management objectives. Regarding mitigation of past losses of sustainability, ER 1110-2-8154 indicates that the Corps can address situations where degraded conditions regarding water quality and/or aquatic or riparian habitats are a result of Corps actions alone, and/or combinations of actions by other governmental agencies and the private sector. Further, Chapter 18 of EP 1165-2-1 (Digest of Water Resources Policies and Authorities) stresses the importance of water quality standards in water quality management planning and development of mitigation projects. Standards can be used as one basis for determining sustainability and the significance of degraded conditions and anticipated impacts from new water resources projects.

11. Corps policies regarding mitigation projects for prior streambank erosion are included in the PGN (ER 1105-2-100), Chapter 15 in the Digest of Water Resources Policies and Authorities (ER 1165-2-1), Section 14 of the Flood Control Act of 1946, Section 103(a) of WRDA 1986, and Section 202(a) of WRDA 1996. These policies are primarily focused on remediating erosion problems threatening public facilities and certain non-profit public services.

12. Another opportunity for enhancing and/or achieving environmental sustainability is via the internal review of future activities and projects to determine if certain practices or design features could be used to enhance sustainability. Project planners and designers can be encouraged to consider resource and ecosystem sustainability in the traditional planning process. Further, environmental staff within the Corps could both participate in and review the products of the planning process. The environmental staff could also coordinate with other federal and state regulatory and resource agencies to aid in "scoping" the activities and projects toward a greater sustainability focus.

8.5.2.2 Design

1. The subject of sustainability should apply not only to specific authorities and mitigation, but also to good environmental design of structures built on or adjacent to the river. Ultimately, this is the responsibility of all who have the potential to affect the

river's environmental components. The Corps of Engineers has a major role on the river and its structures are evident the length of the mainstem.

2. The Corps' Environmental Operating Principles were adopted on 26 March 2002 and include seven principles that collectively reaffirm its commitment to the environment. As they might apply to building structures, five of the seven are particularly relevant:

- Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse and sustainable condition is necessary to support life.
- Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of Corps programs and act accordingly in all appropriate circumstances.
- Seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another.
- Continue to accept corporate responsibility and accountability under the law for activities and decisions under our control that impact human health and welfare and the continued viability of natural systems.
- Seeks ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.

3. The Corps can strive to meet these principles in two ways. The first is through the application of "Green Engineering". According to the US EPA (http://www.epa.gov/oppt/greenengineering/index.html), "green engineering is the design, commercialization, and use of processes and products, which are feasible and economical while minimizing 1) generation of pollution at the source and 2) risk to human health and the environment. Green engineering embraces the concept that decisions to protect human health and the environment can have the greatest impact and cost effectiveness when applied early to the design and development phase of a process or product."

4. Principles of Green Engineering as developed by more than 65 engineers and scientists at the Green Engineering: Defining the Principles Conference, held in Sandestin, Florida in May of 2003 are:

- Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.
- Conserve and improve natural ecosystems while protecting human health and well-being.
- Use life-cycle thinking in all engineering activities.
- Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
- Minimize depletion of natural resources.
- Strive to prevent waste.

- Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
- Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
- Actively engage communities and stakeholders in development of engineering solutions.

5. The second way of integrating sustainability into structures is to consider the design of the structures themselves. Several of the sustainability opportunities identified in 6.4 can be addressed or influenced within the design. Foremost is the potential for providing fish ladders or other means of fish passage within or around the lock structures. When considered in the early phase of design, the additional cost would be low as a percentage of the total cost. Another sustainability feature the Corps could consider at its structures is the dam gate design that allows for better control of pool fluctuations thereby minimizing adverse effects to fish spawning in upstream embayments. The Corps has recently designed an "environmental" dam gate it has installed on Braddock Dam on the Monongahela River that provides for greater oxygenation of water and more efficient release of Volatile Organic Compounds (VOCs) that pass through it. This gate could be used where dissolved oxygen or VOCs are a problem.

6. In the early phase of the site-specific design process, the Corps needs to convene and solicit the input of professionals with expertise in sustainability. In accordance with Environmental Principle #7, the Corps needs to "respect the views of individuals and groups interested in Corps activities, listen to them actively, and learn from their perspective in the search to find innovative win-win solutions to the nations' problems that also protect and enhance the environment."

8.5.3 Operational Capabilities

1. In addition to statutory authorities and mitigation, the Corps can directly affect the sustainability of river-based resources through the operation and maintenance of the existing navigation system. The three Corps Districts with jurisdiction along the Ohio River are currently involved with an ongoing threatened and endangered species Section 7 consultation with the U.S. Fish and Wildlife Service for the effects of operation and maintenance of the Ohio River navigation system and its navigable tributaries on endangered species within the Ohio River basin.

2. Most navigational activities have evolved within each district based on the specific needs of the particular district. In some cases, there is general guidance provided by higher authorities that gives the districts a framework for the work. Within that guidance, each district will tailor the activity to best meet their respective needs.

3. For activities that have the potential for affecting listed species, the Corps districts with jurisdiction on the Ohio River and navigable tributaries will coordinate and establish a general protocol or Standard Operating Procedures (SOPs). This will specifically address ways the activity could be conducted to minimize any impacts.

Development of the protocols or SOPs would be coordinated with the USFWS and state resource agencies (if interested). More specifically, the following measures are examples of operational procedures that could be adopted to enhance sustainability of endangered species. Actions that benefit these species, by their very nature, will support the sustainability of most other species.

8.5.3.1 Geographic Information System O&M and Environmental Database

The three Corps districts with jurisdiction on the Ohio River and its navigable tributaries could establish a Geographic Information System (GIS) that would be shared by the three districts and USFWS. The Corps could maintain the mussel database and keep it up to date. The GIS could be used annually to aid in discussions with the USFWS that address the seasonal dredging plan. The locations of mussel surveys conducted in the main stem and navigable tributaries along with an attached database providing the pertinent information regarding each survey could be maintained. The GIS could include the entire Ohio River Navigation System and be maintained as a working repository for:

- Environmental documentation
- Dredge and Disposal coordinate locations and quantities
- Other relevant appropriate information

8.5.3.2 Dive Surveys

Prior to maintenance dredging of the navigation channel each year, the Corps could conduct initial dive surveys of all new dredge and disposal sites and previously used sites if they haven't been disturbed in the past 5 years. This information could be added to the GIS mussel database and would aid in discussions with the USFWS that address the seasonal dredging plans.

8.5.3.3 Sampling

In order to facilitate captive propagation and reintroduction efforts, each district may require Corps biologists, divers or contractors performing mussel surveys for any reason to collect and hold any listed species. Retention would only be effected at the direction of the UFSWS. Any individual(s) collected would be held only until possession could be passed to an appropriate state or Federal agency representative or other designee (for example, a zoo or aquarium).

8.5.3.4 Navigation Chart Review and Revisions

The CELRD, in consultation with the USFWS, could examine the feasibility of modifying the navigation charts used by the tow pilots to include environmentally sensitive areas. With this information available, the pilots would know the locations of these areas so they can avoid them. Navigation representatives feel that the pilots would be receptive to this if they know what to avoid.

8.5.3.5 Annual Dredging Plan Coordination

The Corps would consult with the State Fish and Wildlife Agencies every year during development of their annual dredging plans. Each Corps district would meet with the appropriate state FWS and their field office(s). This meeting would include review of existing mussel databases, dredging needs and available disposal areas and early identification of environmental issues or concerns specific to the annual plan.

8.5.3.6 Dredge Disposal Habitat Creation

The Corps would use dredge spoil to construct Least Tern habitat wherever feasible. Prior to establishment of sand bars, pre-disposal surveys have been and will continue to be conducted to properly plan and restore this type of riverine habitat such that it does not impact existing mussel beds.

8.5.3.7 Continued Monitoring

The Corps would continue to support monitoring efforts of the FSWS and state agencies. Such support has typically included the assistance of Corps biologists in conducting field surveys and sometimes includes transportation assistance, especially by boat.

8.5.4 Other Agencies' Authorities and Regulatory Responsibilities

1. According to CEQ's Forty Most Asked Questions about NEPA, "all relevant, reasonable mitigation measures that could improve a project are to be identified, even if they are outside the jurisdiction of the lead agency or the cooperating agencies, and thus would not be committed as part of the Record Of Decisions of these agencies (Sections 1502.16(h), 1505.2(c)). This will serve to [46 FR 18032] alert agencies or officials who can implement these extra measures, and will encourage them to do so. Because the EIS is the most comprehensive environmental document, it is an ideal vehicle in which to lay out not only the full range of environmental impacts but also the full spectrum of appropriate mitigation."

2. In recognition that enhancing long-term ecosystem sustainability is a goal of many other agencies and organizations, a summary of some potentially applicable authorities that can be used to address them is provided in **Table 8-7.**

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
All Federal	National Environmental Policy Act (NEPA)	• Requires preparation of an environmental assessment (EA) which would then lead to preparation of Finding of No Significant Impact (FONSI) or an environmental impact statement (EIS) as appropriate, for new construction projects by private and governmental agencies.	Includes water quality & habitat impacts of new projects along the Ohio River such as power plants, Corps projects, permitted activities, and riverfront developments.
	Executive Order 11988, Floodplain Management & Executive Order 11990, Protection of Wetlands	• Prevents federal agencies from contributing to the adverse impacts of floodplain development & modification. • Requires federal agencies to minimize destruction, loss, or degradation of wetlands and to preserve and enhance natural and beneficial values of wetlands.	Restricts federal development in floodplains and wetlands wherever there are practicable alternatives with potential benefits for fish and other aquatic and riparian resources.
	Executive Order 13112, Invasive Species (1999)	• Requires federal agencies to prevent the introduction of invasive species and provide for their control and to minimize their economic, ecological and human health impacts.	Helps to maintain and/or restore the ecological integrity of aquatic and riparian ecosystems.
U.S. Environmental Protection Agency	Clean Water Act (CWA)	• Section 402 establishes National Pollutant Discharge Elimination System (NPDES) for regulating pollution discharges into U.S. waters. • Section 316(a) requires dischargers of heated water effluent to comply with state temperature standards or demonstrate that exceedences are not harmful to fish and wildlife. • Section 316(b) requires	Protects aquatic life within general context of water quality improvements and minimization of impacts from construction or other activities within waters of the US.

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
		cooling water intake structures to reflect best available technology to minimize adverse environmental effects. • Section 401 of Clean Water Act requires applicants proposing any activity, which may result in discharge to U.S. waters, to obtain certification of compliance with state water quality standards. This section is administered by each individual state. • Section 404 authorizes the Administrator of EPA to prohibit the specification of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification as a disposal site, whenever he determines that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife, or recreational areas. • Gives EPA authority to implement pollution control programs. • Requires establishment of water quality standards. • Recognizes need to address nonpoint source pollution.	
	Oil Pollution Act	• Strengthened EPA's ability to prevent & respond to catastrophic oil spills.	Protects aquatic resources from pollution & damage from oil spills.
	Phase 1 & 2 NPDES Program	• Also developed within the CWA, requires municipalities	Reduces pollution characteristics of

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
		and certain industrial and construction sites to adopt Best Management Practices to control nonpoint sources of pollution.	stormwater discharges that may adversely affect aquatic resources in the Ohio River.
	Site Remediation Statutes	• Includes CERCLA, RCRA, • SARA and related state programs that focus on cleanup and restoration of contaminated sites.	Reduces groundwater and soil pollution sources which may adversely impact aquatic resources in the Ohio River.
	National CSO Control Policy	• Published by USEPA, calls for communities to implement long-term plan for combined sewer overflows (CSOs) to comply with the CWA. • Administered through each state's NPDES permit program.	Should reduce pollution from major urban sources with potential benefits for aquatic resources.
	TMDL Program	• Section 303 of Clean Water Act regulates the maximum load of a pollutant a water body can receive and still attain water quality standards.	Presents a more holistic option to water quality management that may be more beneficial to aquatic life than traditional regulatory approaches.
	Safe Drinking Water Act	• Provides for establishment of primary regulations for the protection of public health and secondary regulations related to taste, odor and appearance of drinking water.	Helps protect public water supplies and improves quality of resources.
US Fish & Wildlife Service	Emergency Wetlands Resources Act	• Authorizes purchase of wetlands from Land and Water Conservation fund. • Requires states to include wetlands in Comprehensive Outdoor Recreation Plans. • Provides funding for the Migratory Bird Conservation Fund.	Benefits sustainability by encouraging federal-state cooperation in wetlands protection and outlines funding mechanisms.
	Endangered Species Act	• Authorizes determination & listing of threatened & endangered species and	Establishes framework for protection of threatened &

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
		critical habitat. • Prohibits unauthorized taking, possession, sale & transport of endangered species. • Provides for land acquisition to protect endangered species. • Requires Federal Agencies to consult with the USFWS or NMFS concerning effects of actions on listed species and critical habitats.	endangered species and critical habitats that are important components of the ecosystems.
	Fish & Wildlife Act	• Requires USDI to take steps for management & protection of fish & wildlife resources through research, acquisition of land & water & other means.	Establishes a comprehensive national fish & wildlife policy applicable to fish and other aquatic and riparian resources.
	Fish & Wildlife Coordination Act	• Requires that whenever water resources projects are planned by a federal agency, that agency shall consult with the USFWS and with appropriate state agencies with a view toward wildlife conservation.	Provides for equal consideration and coordination of fish and wildlife conservation with other aspects of water resources development.
	National Wildlife Refuge System Administration Act & National Wildlife Refuge System Improvement Act	• Provide guidance for management and public use of refuge system, including development of comprehensive conservation plan for each refuge.	Guides management & public use of Ohio River Islands National Wildlife Refuge.
	Migratory Bird Conservation Act	• Provides for the acquisition and maintenance of public land for habitat preservation of migratory birds.	Applies to land, water and transitional areas, e.g., riparian areas.
	Migratory Bird Treaty Act	• Implements various treaties and conventions between the U.S., Canada, Mexico, Japan and the former Soviet Union for the protection of migratory birds. Prohibits taking, killing and	Protects migratory birds utilizing riparian and floodplain areas.

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
		possession.	
	North American Wetlands Conservation Act	• Provides funding and implementation of the North American Waterfowl Management Plan & North American nations wetlands agreement.	Provides funding support for migratory bird conservation in the Ohio River valley.
	Refuge Recreation Act	• Authorizes USDI to administer conservation areas for recreational use when such uses do not interfere with an area's primary purpose.	Allows recreational use of Ohio River Islands National Wildlife Refuge.
US Dept. of Trans-portation and Aquatic Nuisance Species Task Force	National Invasive Species Act	• Requires all vessels operating in US waters that are equipped with ballast tanks to comply with guidelines designed to prevent and reduce the dispersal of aquatic nuisance species.	Helps reduce the further introduction and dispersal of non-native, invasive species that can disrupt aquatic ecosystems.
USDA Natural Resources Conservation Service	Farm Security and Rural Investment Act of 2002 (aka Farm Bill)	• Includes various incentive programs to promote installation of riparian buffers. • Swampbuster provisions withhold certain USDA benefits from farmers who convert or modify wetlands. • Offers opportunities for wetlands mitigation.	Helps improve and/or preserve environmental functions & values of riparian areas in the Ohio River floodplain.
U.S. Coast Guard	Spill Response	• Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the Clean Water Act.	Minimizes adverse impacts of spills and discharges on aquatic resources and on water quality.
Federal Emergency	National Flood Insurance Act	• Encourages adoption of state & local floodplain regulations	Limits development impacts in riparian

Table 8-7
Environmental Sustainability Authorities of Other Federal Agencies

Agency	Law/Program	Key Components	Relevance to Sustainability
Management Agency (FEMA)		restricting certain types of development within floodplains.	areas. Helps protect stream/floodplain connectivity.
State agencies	State Water Quality Certification	• Section 401 of the Clean Water Act (CWA) requires certification from state or interstate water control agencies that a project is in compliance with established effluent limits and water quality standards.	Provides opportunity for state or interstate scrutiny of such actions on fish and other aquatic resources.
	State Fishing Regulations	• Establish regulations that consider fish habitat and reproduction. Ohio River state resource agencies have established an Ohio River Fisheries Management Team to coordinate a variety of management issues and programs.	Has potential to enhance environmental sustainability of Ohio River fish communities through long-term collaborative fisheries management efforts.
KY Dept. of Fish & Wildlife Resources	Kentucky Mussel Refuges Act	• Establishes sanctuaries near KY islands within Ohio River Islands National Wildlife Refuge.	Prohibits commercial mussel harvesting and collecting from these refuges.
Ohio River Valley Sanitation Commission (ORSANCO)	ORSANCO Monitoring	• Encompasses ongoing water quality and aquatic ecology monitoring programs by the Ohio River Valley Water Sanitation Commission. • Helps ensure water quality standards are consistent among Ohio River states.	Helps track trends in water quality and biological communities and provides database that can inform environmental decision-making. Reduces discrepancies in interjurisdictional waters of the Ohio River.

In addition to programs of other agencies listed above, there are numerous grants administered by Federal agencies. Several of these that could also be used to improve ecosystem sustainability are listed below:

USFWS:

- Federal Aid in Sport Fish Restoration
- Federal Aid in Wildlife Restoration
- Clean Vessel Act

- State Wildlife Grant Program
- Landowner Incentive Program
- North American Wetlands Conservation Grant
- Neotropical Migratory Bird Conservation Act Grants
- Pirvate Stewardship Programs
- Coorperative Endangered Species Conservation Fund
- Partners for Fish and Wildlife Assistance

USEPA:

- Wetland Program Development Grants
- Five Star Restoration Program
- State Revolving Fund

NRCS::

- Wetlands Reserve Program
- Healthy Forest Reserve Program
- Conservation of Private Grazing Lands
- Cooperative Conservation Partnership Initiative
- Conservation Reserve Program
- Conservation Technical Assistance
- Grazing Lands Conservation Initiative

8.6 WITHOUT-PROJECT ALTERNATIVES

Without Project Condition alternatives are developed by combining the measures surviving the initial screening. Because maintenance and its effect on the satisfactory performance of the aging locks is a key concern, considerable effort was devoted to identifying the least-cost maintenance policy for all locks. This encompasses consideration of both repair costs and any associated navigation delay costs due to additional congestion around the locks. Efficient operation of the existing facilities is a very important consideration, especially during closures of any main chamber maintenance when all traffic is funneled through a small auxiliary chamber. Two WOPC alternatives are described below for the initial screening.

8.6.1 Federal Disinvestment

In essence, this option would close the Ohio River Mainstem System down, either all at once or in a "piecemeal fashion" dictated by the order in which components fail due to age or fatigue. There would not be any component replacement, only routine maintenance and possibly cyclical maintenance. Structures could be removed after closed (decommissioned) and the river could return to a more natural state. The objective of this study is to determine a long-term maintenance and lock modernization strategy to

provide reliable navigation along the Ohio River Mainstem. Companies using the Ohio River System (ORS) ship over $30 billion worth of commodities by barge, saving over $2 billion in transportation costs annually. These savings result in additional national output estimated at over $11 billion, which makes possible approximately 100,000 jobs and $3 billion in income.[6] Closure of the Ohio River would necessitate that this traffic be diverted to alternative markets or more costly land-based transportation modes or possibly even eliminated from the economy. The potential economic impact of this alternative would be severe. This large economic benefit of the navigation system along the Ohio River mainstem justifies a continued Federal Interest to ensure future navigability of this system. Further, disinvestment in the system would fail to meet two of the three study objectives for the ORMSS. Therefore, the Federal Disinvestment alternative is eliminated from further detailed analysis at this point.

[6] Regional Economic Development Impacts on the Ohio River Basin due to Commodity Savings Along the Ohio River System, September 1999, Marianne Matheny, NAB and Dennis Robinson, IWR

8.6.2 Reactive Maintenance Alternative

The Reactive Maintenance Alternative (RMA) would keep the existing system operating with all of the maintenance measures and operational and low cost structural measures carried forward as listed in **Tables 8-4 and 8-5**, respectively. Any and all repairs and component replacements would only be in reaction to component failures, or unscheduled, but would be accomplished quickly under emergency conditions. Annual and cyclical maintenance would be performed. Existing operational policies during periods of high congestion would be implemented and features such as all existing mooring cells and existing tow haulage units would be maintained. Also included are the following authorized improvements previously noted in Section 2.2.1.

- Olmsted L/D – Olmsted L/D is modeled throughout the period of analysis. Since this investment is under construction, this project is assumed operational by 2010 and no federal costs beyond 2010 are included.

- Myers auxiliary chamber extension – Myers auxiliary lock extension is under construction so Myers is included in the WOPC as a twin 1200' x 110' project. However, the project is not expected to become operational until 2012 so Federal costs beyond 2010 are included

- Greenup auxiliary chamber extension and main chamber rehab – Greenup is included in the WOPC as a twin 1200' x 110' project with a rehabbed main chamber. Federal costs beyond 2010 are only included for the major rehabilitation.

- McAlpine lock replacement – This investment became operational in 2009 and no federal costs beyond 2010 are included.

This alternative represents the WOPC.

8.7 EVALUATION OF THE REACTIVE MAINTENANCE ALTERNATIVE (WITHOUT PROJECT CONDITION)

Alternative WOPC System Investment Plans are evaluated for each traffic demand scenario to determine performance both at the lock and system-wide levels. Additional details are contained in **Sections 8 and 9 of the Economics Appendix**. Economics are addressed in Section 8.7.1; environmental issues are included in Sections 8.7.2 and 8.7.3. The focus of this analysis is evaluation of total costs, including Operations and Maintenance expenditures by the Corps and the costs incurred by commercial navigation. Corps and navigation industry costs are weighted equally.

8.7.1 Economic Performance

8.7.1.1 Methodology

1. The principal factor driving the variation in costs of WOPC alternatives is the performance of critical lock components required to keep the chamber open. Component performance in the form of annual probabilities (hazard rates) that these components may fail is evaluated through reliability analyses and assessed to determine repair or replacement needs through ORNIM.

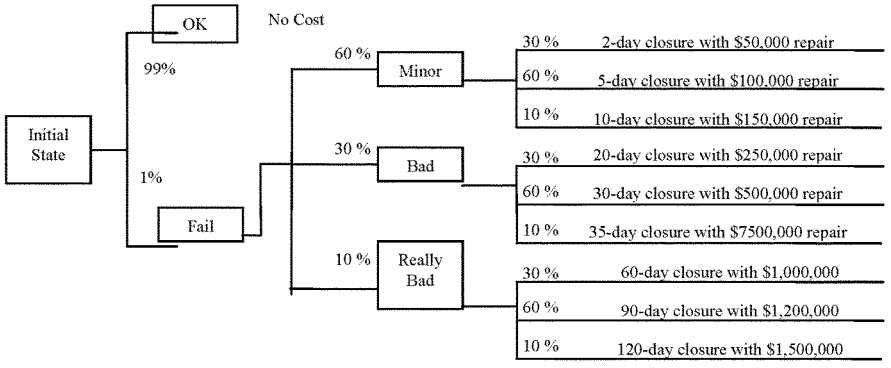
2. The RMA defers all repairs and replacement of critical components until after failure. The key outputs of the economic analysis of this alternative are the costs due to unexpected failures of the major components, both to repair or replace the failed component and the associated lock chamber closure times and associated navigation delay costs directly attributable to the closures. The critical inputs to this analysis are the hazard rates for each component, where a hazard rate for a given year is defined as the probability of failure during a given year assuming that no failure had occurred up to the beginning of the year, the potential failure scenarios and their likelihoods (given that a failure occurs), and the economic consequences associated with those scenarios.

3. All reliability models are developed to look at "significant" levels of failure that result in closure of a chamber and have an effect in the overall economic evaluation. For example, modeling of fuses in an overall electrical system is not warranted because their failure is not a major consequence in terms of money or safety. However, electrical power controls are modeled because their failure can have a major impact on both navigation and replacement costs. This same process is applied to all major components analyzed using reliability methods. The reliability models attempt to address failure mechanisms that are not addressed by routine maintenance, such as fatigue life and loss of strength due to corrosion. Therefore, it is assumed that overall reliability of major components such as miter gates and culvert valves are not significantly affected by routine or cyclical maintenance. Such maintenance helps to keep gates aligned and in proper working order but it does not address issues such as fatigue life and corrosion. For more details on how the reliability results are incorporated into the economic models please refer to the Section 7 of the **Economics Appendix**.

4. The basic economic evaluation process for any alternative can be represented by a repair "event tree" as shown in **Figure 8-1**. The probability of <u>any</u> failure for year (t) is given by the hazard rate, 1% in this case. Conversely, the probability that there are no failures in year (t) is given by one minus the hazard rate, or 99% here. The potential degrees of failure (noted as minor, bad and very bad in this illustration) and the necessary repair cost and associated chamber closure requirements are assigned probabilities based upon engineering judgment[7]. In this example, there are three possible repair options for each degree of failure. Repairs due to a minor failure of the component would cost between $50,000 and $150,000 and involve a lock closure of between 2 and 10 days.

[7] The probability of any particular degree of failure in year (t) is the product of the hazard rate in year t {h(t)} and the conditional probability of the degree of failure given that there the component fails.

Figure 8-1
EXAMPLE EVENT TREE



5. All event trees except those for the lock and approach walls at Emsworth, Dashields, and Montgomery account for single modes of failure. Event trees for these walls accounted for multiple modes of failure and were developed by aggregating (lumping) the individual event trees for all failure modes. The results from this aggregation process were checked against the total costs based on separate analyses of the individual failure modes. Additional details on the event tree derivation are provided in the **Engineering Appendix**. The reliability of twenty components was analyzed at each mainstem lock chamber; however, only those with some minimal threshold likelihood of failure during the analysis period were carried forward for economic analysis with this methodology. The subset of components varied from site to site.

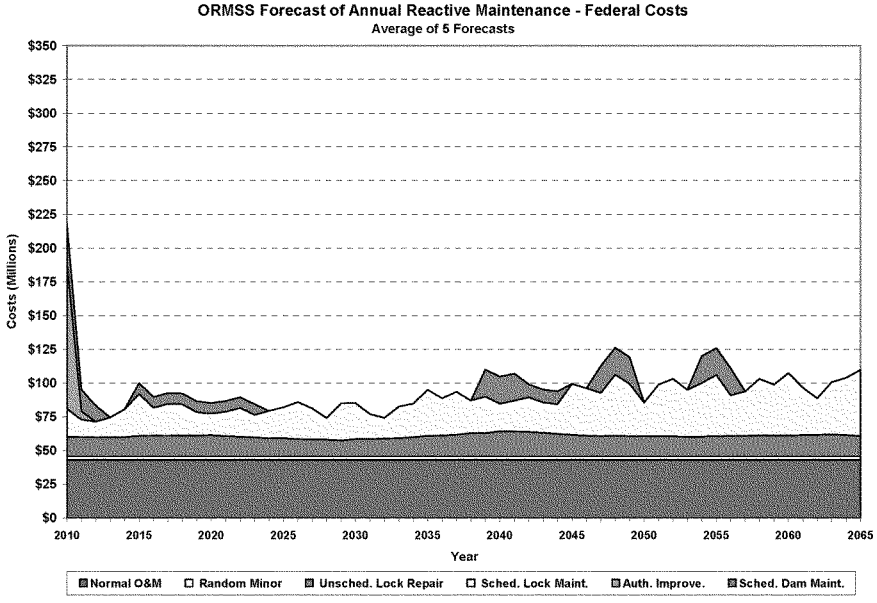
8.7.1.2 Ohio River Mainstem and Project Costs

1. The total costs for the Reactive Maintenance Alternative include operations and maintenance costs incurred by the Corps, including routine maintenance, cyclic (scheduled) maintenance, and unscheduled repair costs at all nineteen Ohio River facilities, as well as costs to construct all authorized improvements. Given the engineering hazard functions and event trees for the lock components considered, ORNIM was run for each project to calculate the expected repair costs under each of the five different traffic forecast scenarios. **Attachment 3 of the Economics Appendix** provides a more detailed discussion of this analysis.

2. **Figure 8-2** shows forecast reactive maintenance funding needs over time aggregated for all nineteen Ohio River facilities and averaged over all five traffic scenarios. Much of the work for authorized improvements occurs prior to 2010 and is not shown in **Figure 8-2**. The high costs for authorized improvements reflect the completion of the Myers auxiliary lock extension and major rehabilitation of the Greenup main lock chamber. The high cost for scheduled dam maintenance reflects the completion of the on-going MR of Emsworth dams. Economic costs for all "sunk costs" prior to the year

2010 are included in all economic cost tabulations for the WOPC as well as WPC alternatives as presented in Section 10. Overall, this analysis shows an average annual expenditure of around $100.0 million is required to sustain navigation on the Ohio River from 2010-2070 with a reactive maintenance strategy.

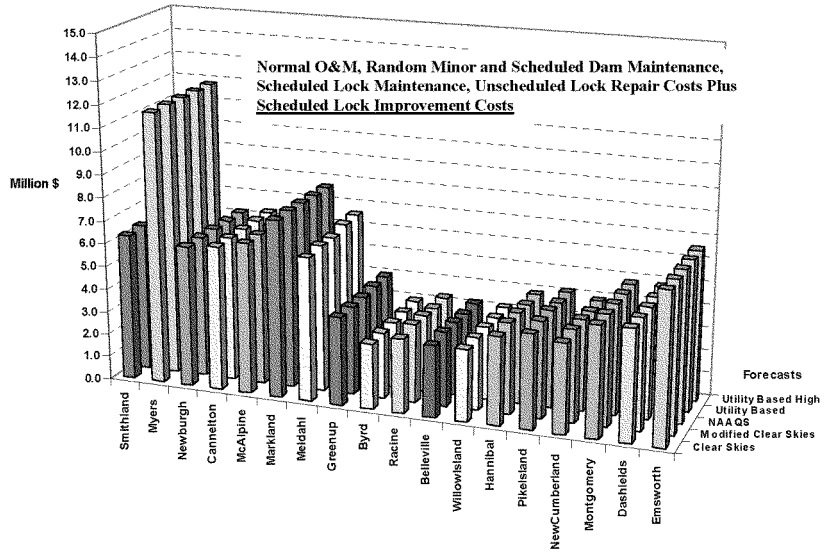
FIGURE 8-2



3. **Figure 8-3** displays average annual Federal costs for the reactive maintenance strategy by project and by traffic forecast averaged over all five forecasts. The graph displays all maintenance cost categories as well as the costs for authorized improvements. High reactive maintenance needs are seen on the upper and lower Ohio projects.

4. Section 4 of **Attachment 3 Project Maintenance Analysis** displays each project's component-level, expected transit costs and repair costs for each traffic forecast scenario with a reactive maintenance strategy.

FIGURE 8- 3
Reactive Maintenance
Average Annual Project Costs
(2010-2070, 5 1/8%, FY 03$)



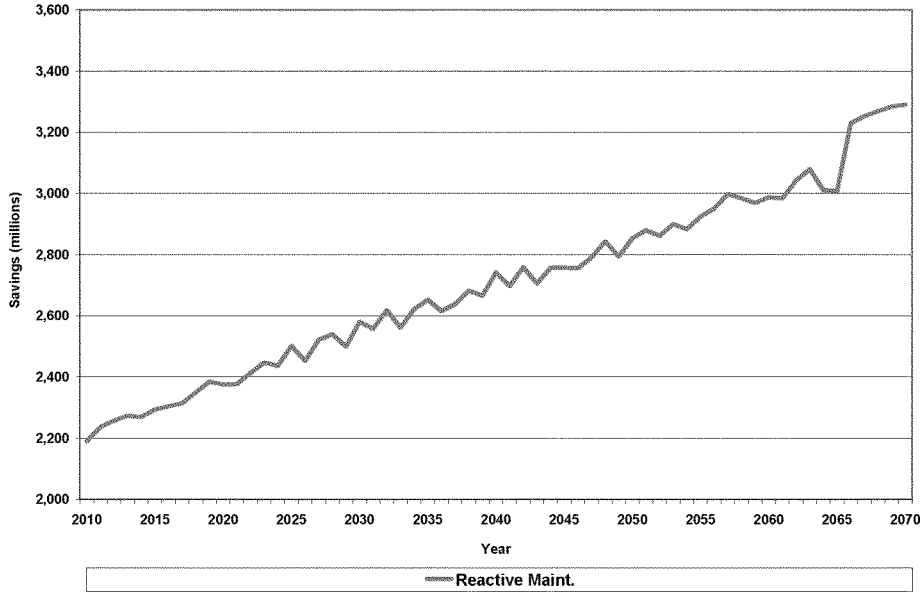
8.7.1.3 Ohio River Mainstem Benefits

1. The primary benefit for Federal investment in the inland waterways is the collective transportation cost savings for barge shipment over the least-costly alternative routing or transportation mode. The benefit is referred to as transportation rate savings. Corps regulation recognizes transportation rate savings or cost reduction as a National Economic Development (NED) benefit. (See **Attachment 6 of the Economics Appendix** for a detailed discussion on derivation of transportation rate savings.)

2. In ORMSS, the total or National Economic Development (NED) benefits are calculated from the total equilibrium waterway traffic transportation rate savings less any eroded savings from congestion or delay due to unscheduled repair closures. Equilibrium waterway savings for each traffic scenario are determined by the ORNIM, where equilibrium is defined to occur when every movement fully assigned to the waterway has a lower cost-per-ton by water routing than by land, resulting in a positive rate-savings, while every movement fully assigned to the land routing has a lower cost-per-ton by land than by water. Two iterations of ORNIM are required; the first to determine the equilibrium traffic and associated total transportation savings compared to the lowest cost alternative transportation option for all commercial traffic that considers only scheduled closures (cyclical maintenance in the case of the WOPC). A second iteration then

determines impacts due to unscheduled lock chamber closures and the added delay costs or reduced savings due to those closures and recalculates the transportation savings. **Figure 8-4** displays system transportation savings including reduced savings averaged over all 5 traffic forecast scenarios for the base-level reactive maintenance WOPC. Average annual system NED benefits are $2.46 billion from 2010-2070.

FIGURE 8-4
Reactive Maintenance System Transportation Annual Savings
Average of 5 Forecasts



8.7.1.4 Ohio River Mainstem Statistics

1. **Table 8-8** summarizes the expected mainstem system benefits, eroded transportation savings and costs by cost category for the reactive maintenance alternative for each of the five traffic forecast scenarios. Average annual system benefits range from $2.25 to $2.46 billion, reflecting reduced or eroded savings due to unscheduled repairs of $76 to $124 million annually.

TABLE 8-8
Reactive Maintenance*
(Without Project Condition)
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Reactive Maintenance Benefits					
Equilibrium Waterway Savings	$2,328.6	$2,493.5	$2,476.0	$2,536.4	$2,580.5
Reduced Savings from Unscheduled Repair	($75.8)	($119.8)	($124.1)	($107.7)	($120.3)
Total System Benefits	**$2,252.8**	**$2,373.7**	**$2,351.8**	**$2,428.7**	**$2,460.1**
Reactive Maintenance Costs					
Scheduled Lock Maintenance	$ 23.1	$ 23.1	$ 23.1	$ 23.1	$ 23.1
Scheduled Dam Maintenance	$ 6.9	$ 6.9	$ 6.9	$ 6.9	$ 6.9
Scheduled Lock Improvements**	$ 5.8	$ 5.8	$ 5.8	$ 5.8	$ 5.8
Unscheduled Lock Repair	$ 14.0	$ 15.1	$ 15.0	$ 14.7	$ 15.0
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$99.0**	**$100.1**	**$100.0**	**$99.8**	**$100.1**
Net Benefits	**$2,153.8**	**$2,273.6**	**$2,251.8**	**$2,328.9**	**$2,360.1**
BCR	**22.7**	**23.7**	**23.5**	**24.3**	**24.6**

**Sums and differences may reflect rounding error.*

*** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include the authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11. Other authorized improvements are modeled as complete and on-line before 2010 and those costs are not included.*

2. Total system costs in **Table 8.8** are the expected average annual Federal and Trust Fund expenditures needed to maintain Ohio River navigation infrastructure under the reactive maintenance strategy. Refer to Section 8.3.1 for details of each maintenance cost category. The Federal costs represent the costs to the Federal government to maintain, repair, or improve the navigation projects. Scheduled lock and dam maintenance costs are what the Federal government pays for the scheduled cyclical maintenance of the mainstem projects. Scheduled improvement costs are the Federal and Trust Fund costs remaining as of 2010 to complete authorized mainstem projects (Greenup and J.T. Myers). Unscheduled repair costs are the Federal costs associated with the unscheduled repair and replacement of lock components. Normal O&M is a fixed cost to the Federal government to staff and supply the project regardless of the project's ability to accommodate any traffic. Random minor costs are also incurred equally in all traffic scenarios. Total system costs are the average annual Federal expenditures expected to maintain Ohio River navigation infrastructure under the reactive maintenance

strategy. The Federal costs represent the costs to the Federal government to maintain, repair or improve the navigation projects. Average annual system costs range from $99.0 to $100.1 million. Net benefits range from $2.15 to $2.36 billion.

3. It is instructive to consider the average annual delays and annual tonnages processed at several representative locks in the WOPC, Montgomery for the upper Ohio River comprised of EDM and Racine for the middle Ohio River. At Montgomery, the average annual delays determined by the ORNIM in every year (2010-2070) exceed by an order of magnitude or more the average delays shown in Table 6.2 for the period 1994-2003. These delays are likely due to frequent unscheduled lock closures to repair failed components. The tonnages processed through Montgomery nearly equal demands until around 2020 when tonnage processed falls below demands in **Table 8-3** in many years, ranging from 0.5 million to 2.0 million below those demands. At Racine, annual average delays range from 1.0 to about 5 hours per tow in years when the main chamber is dewatered, compared to about 0.5 hours per tow during 2000-2004. These delays cause the diversion of 0.2 to 1.0 million annually of the tons demanded as shown in **Table 8-3**.

8.7.2 Impacts to Valued Environmental Components

1. Potential direct and indirect effects of the 10 navigation-related measures included in WOPC Reactive Maintenance Alternative (RMA) are presented in **Table 8-9**. The 10 measures are divided into maintenance actions, operational actions, and low-cost structural actions. Further, each action is briefly described. The major portion of **Table 8-9** is associated with "cells" containing descriptive information on the effects (impacts) of the 10 measures on the six major Valued Ecological Components (VECs); namely, water quality, fish, mussels, riparian resources, recreation, and health and safety. These six VECs were designated as major based on inputs from the Interagency Working Group and various publics, recognition of their inherent importance in the environment of the Ohio River Mainstem, and their susceptibility to damage from multiple governmental and private actions in the Mainstem environs. **Table 8-9** also includes codes in the upper parts of cells to denote whether the anticipated effects are detrimental or undesirable (denoted by a "-" sign), beneficial or desirable (denoted by a "+" sign), or a mixture (denoted by a "-/+" sign).

TABLE 8-9

POTENTIAL ENVIRONMENTAL EFFECTS ON MAJOR OHIO RIVER VECS

IN THE WITHOUT PROJECT REACTIVE MAINTENANCE ALTERNATIVE

WOPC Action	Description of Action	Impacts on Major VECS					
		Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	Health & Safety
Maintenance Actions							
Routine Maintenance	Small jobs and minor repairs. See Table 8.2 for details.	Impacts are anticipated to be very limited; if care is taken in handling lubricants and other materials, BMPs are used to minimize erosion, and Corps standard procedures followed. Environmental Management Systems type approaches could contribute to long term reduction of cumulative maintenance impacts; e.g. lawn maintenance alternatives to reduce mowing and use of fertilizers & herbicides.				No impacts to recreation are anticipated because lock closures do not occur during routine maintenance.	**Impacts are anticipated to be very limited, if care is taken in handling harmful materials and equipment.**
Cyclical Maintenance	Scheduled inspections and repairs to major components, including chamber dewatering	+/- In the long-term, cyclical maintenance would benefit water quality, by ensuring safe passage of vessels through the locks and lessening the need for emergency repairs. Short term negative impacts to	-/+ Dewatering would interfere with limited upstream movement of fish through locks and possible damage to tailwater areas. Cyclical maintenance, however, would minimize	-/+ Lock dewatering could alter flows to downstream mussel habitat and possibly directly damage beds, depending on their location. As with fish, cyclical maintenance, could minimize unscheduled repairs that	- Chamber dewatering would increase queues and potential barge toe-ins and tie offs that can damage riparian resources. Operational and low coast structural actions can prevent some of this damage.	- Chamber dewatering would limit or perhaps eliminate lockages by recreational vessels as commercial vessels would be given priority. If maintenance procedures required long-term closures, measurable economic losses related to recreation could occur.	**Impacts are anticipated to be very limited, if care is taken in handling harmful materials and equipment.**

		water quality may include increased turbidity during dewatering & decreases in oxygen levels.	unscheduled repairs that could cause greater damage to fish habitat. Chamber dewatering would increase queuing and potentially directly scour fish habitat or interfere with spawning and feeding.	could cause greater damage to mussels and their habitat. Chamber dewatering would increase queuing and potentially cause direct damage to mussel beds or interfere with reproduction and feeding.			
Unscheduled Repairs	Includes all unscheduled repairs to major components, often under emergency conditions.	- Negative impacts can occur to water quantity and to fish, mussels, and riparian resources, if failure of major L & D components alters water levels or releases harmful substances into the aquatic environment. The extent of the damage in part would be related to the duration of emergency conditions, as well as time of year. Emergency repairs may overlook measures/opportunities to avoid, minimize or mitigate for environmental impacts, increasing risk of experiencing otherwise avoidable impacts. Emergency repairs with unscheduled closures may exacerbate impacts of queuing.				- Negative impacts to recreation would occur relative to the duration of a lock closure and time of year it occurred.	- **Because emergency conditions are less predictable than routine or cyclical maintenance, special precautions are essential to ensure worker safety in these circumstances.**
Operational Actions							
N-Up/N-Down Lockage Policy	Involves locking a given number of tows (N) in the same direction, then allowing the same	+ Reduces queuing that wastes fuel	+ Facilitates tow movement	+ Facilitates tow movement near L & Ds,	+ Reduces queuing and possible bank	+ Facilitates movement of tows through locks and	+ **Facilitates orderly procession of**

	number to proceed in the opposite direction to increase lock efficiency and reduce queuing.	and can increase turbidity; lowers potential for accidental spills of materials shipped.	through sensitive tailwater habitat.	reducing potential damage to nearby mussel beds.	scour and erosion and damage to shoreline vegetation if vessels push into banks while waiting in queue.	reduces time recreational vessels must remain in queues.	**tows through locks and decreases potential for accidents that may cause injury or spills of hazardous and other harmful materials.**
Advanced Notice of Main Chamber Closures	Notification of towing industry and other river users prior to main chamber closures promotes better management of vessels during closures.	+ Similar to N-up, N-down in reducing harmful effects of queuing. Additionally, would benefit WQ by reducing traffic on river during closures.	+ Similar to N-up, N-down in reducing harmful effects of tows in tailwater habitat. Additionally, would benefit fish habitat somewhat by reducing traffic on river during closures.	+ Similar to N-up, N-down in reducing harmful effects of queuing near or on mussel beds. Additionally, would benefit mussels by reducing traffic on river during closures.	+ Similar to N-up, N-down in reducing harmful effects of queuing and tying off along banks. Additionally, would benefit riparian resources by reducing traffic on river during closures.	+ Reduces number of tows passing through locks and reduces time recreational vessels must remain in queues, if allowed to use operational lock chamber.	+ **Reduces number of tows passing through locks and decreases potential for accidents that may cause injury or spills of hazardous and other harmful materials.**
Adjustment of Shipping Schedules	Involves efforts by towing industry to plan pre- and-post closure shipments, ship via other routes or modes, deliver from alternative sources, and rearrange shipments to minimize trips through L	+ Impacts very similar to Advanced Notice of Lock Chamber Closures.	+ Impacts very similar to Advanced Notice of Lock Chamber Closures.	+ Impacts very similar to Advanced Notice of Lock Chamber Closures.	+ Impacts very similar to Advanced Notice of Lock Chamber Closures.	+ Impacts very similar to Advanced Notice of Lock Chamber Closures.	+ **Impacts very similar to Advanced Notice of Lock Chamber Closures.**

	& Ds.						
Industry Self-Help	Involves helper towboats that assist tow locking by extracting unpowered cuts of barges from lock chamber and then moving them in a refleeting site away from the L & D to increase lock efficiency and reduce queuing.	+ Impacts very similar to N-up/N-down policy.	+ Impacts very similar to N-up/N-down Policy. Damage to fish habitat could occur in refleeting areas depending on locations.	+ Impacts very similar to N-up/N-down Policy. Damage to mussel habitat could occur in refleeting areas depending on locations.	+ Impacts very similar to N-up/N-down policy.	+ Impacts very similar to N-up/N-down policy. Boater education about refleeting areas could avoid potential conflicts between commercial and recreational vessels.	+ **Impacts very similar to N-up/N-down policy.**
Low-Cost Structural Actions							
Tow Haulage	Involves using equipment that expedites the two-cut lockage process when helper boats are not available; increases lock efficiency and reduces queuing. Not available or feasible at every L & D project.	+ By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.	+ By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.	+ By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.	+ By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.	+ By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.	+ **By reducing queuing, impacts are very similar to N-up/N-down policy & self-help.**
Mooring Cells	Located at arrival points to locks and used to tie off while tows wait in queues; eliminate or reduce queuing along banks; reduce turbidity and air impacts from engine idling.	-/+ Negative impacts to WQ during installation would be limited primarily to increased turbidity, although additional adverse impacts	-/+ Negative impacts to fish habitat could occur during installation. Further, heavy use of mooring areas would restrict fish use for feeding and	-/+ Negative impacts to mussel habitat could occur during installation. Such impacts may extend throughout the use of the mooring area. Positive impacts would	-/+ Negative impacts to mussel habitat could occur during installation depending on proximity to shore and scouring by vessel prop wash. Positive impacts	-/+ Limited negative impacts to recreation may occur when mooring cells are installed. If such cells are clearly marked, recreational vessel accidents should be minimized. The overall reduction in queuing near locks should make	-/+ **Negative impacts to H & S could occur during installation unless proper safety precautions are taken. Once installed, mooring cells minimize dispersed barge**

		would occur if fuel spilled. Positive impacts would be related to reductions in queuing and fuel consumption.	reproduction. Positive impacts would be related to reductions in queuing and prevention of more dispersed damage to fish habitat.	be related to reductions in queuing and prevention of more dispersed damage to mussel habitat.	would be related to reductions in mooring along banks that can damage riparian vegetation and cause erosion and bottom scouring,.	recreational lockages safer and more efficient.	**traffic, which otherwise may cause accidents.**
Temporary Mooring Cells during Lock Closures	**Same as above, but placed on shorter-term basis.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term. Need to be clearly marked (even if temporary) so recreational river users become aware of them and can avoid accidents.**	-/+ **Impacts similar to more permanent mooring cells, but shorter term. Need to be clearly marked (even if temporary) so recreational river users become aware of them and can avoid accidents.**

2. Based upon a careful review of the descriptive information in **Table 8-9,** the following general observations can be made:

- Regarding the three maintenance actions, the small jobs and minor repairs associated with routine maintenance would cause only localized and limited effects on the six VECs. Cyclical maintenance actions related to major lock components would be expected to require lock chamber dewatering. Short-term detrimental effects could occur relative to increased water turbidity, interference with upstream movement of fish, disruptions in downstream mussel habitat, damage to riparian resources due to the queuing of tows and their bank toe-ins and tie-offs, and disruption of recreational boat lockages. For emergency conditions requiring unscheduled repairs to major components, negative (detrimental) impacts would be expected on all VECs. The duration of the emergency conditions and the time of the year would influence the extent of the impacts.

- Regarding the four operational actions in **Table 8-9**, each is expected to reduce tow queuing prior to passage through the locks, and to facilitate tow movement through the locks in a more timely manner. As a result, beneficial impacts (effects) on the six VECs are expected from reductions in localized water turbidity levels, decreases in aquatic and riparian habitat disruptions, and lowered potentials for accidental spills of barged materials.

- Relative to the three low-cost structural actions in **Table 8-9**, tow haulage is expected to reduce queuing and thus provide beneficial impacts (effects) on the six VECs. Such beneficial effects would result from reductions in localized water turbidity levels; decreases in disruptions to habitats for fish, mussels, and riparian resources; and lowered accident potentials. Both permanent and temporary mooring cells are expected to cause negative and positive effects on the six VECs. Depending upon their location, negative effects could occur from mooring cells if they are over or near mussel beds, if they disrupt fish habitat, or if they are near erodible shorelines. Positive effects related to appropriately located mooring cells could result from reductions in queuing and the minimization of dispersed damages to habitats.

3. From the perspective of the potentially impacted VECs, the following can be noted from **Table 8-9**:

- Because of the localized and limited nature of effects from routine maintenance, the water quality VEC would not be affected. However, this VEC would be negatively impacted, albeit on a localized basis and for the short term, by cyclical maintenance and unscheduled repairs. These impacts, resulting from lock closures, queuing and construction activities would be partially attenuated by the 4 operational actions and the 3 low-cost structural actions described in **Table 8-9**. These scheduled and unscheduled repair activities are necessary to maintain the current level of commercial traffic on the Ohio River. Accordingly, the WOPC

alternative, which is comprised of the 10 actions in **Table 8-9**, would not cause large-scale detrimental effects on the water quality VEC. Rather, beneficial effects would accrue over the long term by minimizing localized turbidity levels from tow queuing, particularly in tailwater areas below the locks.

- An important exception to the above generalization may occur when unscheduled repairs are necessitated by extraordinary events such as the pool loss at Bellville in 2005 or the failure of major lock components that result in long closures with minimal warning to the barge industry. Emergency repairs under such conditions may preclude opportunities to avoid or minimize environmental impacts while increasing impacts from queuing and construction site activities. Additionally, beneficial effects associated with the 4 operational and 3 low-cost structural actions may be reduced due to delays or inability to provide such measures during the emergency response. The negative consequences of such events could impact all six of the VECs addressed in **Table 8-9.**

- Routine maintenance, in combination with standard measures to avoid spills or other impacts related to such activity, is not expected to have any affect on the Fish VEC. Cyclical maintenance and unscheduled repairs would be expected to produce temporary, localized impacts, including sediment resuspension and deposition, disruption of seasonal feeding or spawning patterns, and disruption of fry and larval life stages. The severity of such impacts would be reduced by implementation of the 4 operational actions and the 3 low-cost structural actions. Additionally, completion of such repairs will contribute to the maintenance of efficient movement of commercial traffic through the locks, which would result in reduced impacts to fish during normal operations.

- The mussels VEC comprises the resource group that is most sensitive to construction and queuing related impacts. However, mussels are not expected to be seriously affected by routine maintenance activities so long as accident and spill prevention standards are observed. Mussels would be susceptible to impacts from cyclical maintenance and unscheduled repairs, including turbidity, scouring and sediment deposition, that could disrupt feeding and spawning activities. In some cases, the duration of impacts such as sediment deposition could continue beyond the actual periods of disturbance. The effectiveness of operational and structural practices designed to minimize such impacts would be enhanced by carefully documenting the location of mussel populations in proximity to the project and potential queuing areas prior to initiation of such disturbances. In the case of mooring cells, care must be taken to avoid or minimize potential impacts related to the location and construction of such structures.

- Riparian resources are unlikely to be impacted by routine maintenance activities, but can be damaged by barge toe-ins and tie-offs during periods of queuing necessitated by maintenance or repair activities. The 4 operational measures, plus tow haulage, can somewhat reduce such impacts. Where available, mooring cells have the potential to nearly eliminate queuing related impacts.

- It is highly unlikely that recreational activities would be influenced by routine maintenance. In the case of lock closures required for cyclical maintenance or unscheduled repairs, passage through the auxiliary lock may be suspended. Access to visitor facilities at the lock and dam project may also be closed during the construction phase. These inconveniences are somewhat compensated by the general availability of alternative recreational opportunities elsewhere on the Ohio River. When recreational access is not closed, the operational and low-cost structural measures associated with movement of commercial traffic through the construction area would have limited positive impacts on recreational activity. Ultimately, completion of maintenance and repair activities is necessary to long term provision of recreational opportunities during periods of normal operation.

- Health and safety impacts of routine maintenance should be very limited, in proportion to continued observance of routine safety standards at the lock and dam project. During cyclical maintenance or unscheduled repairs, risk factors become elevated and more proactive safety standards are required. Closure of the lock and dam area to visitors and temporary suspension of recreational lockages are examples of such proactive measures. The 4 operational measures and 3 low-cost structural options also contribute to safety by helping reduce congestion in the vicinity of the construction activity.

8.7.3 Cumulative Effects

The final consideration related to the direct and indirect effects of the WOPC alternative, referred to as the Reactive Maintenance Alternative (RMA), is focused on two issues – the anticipated relative contribution of the RMA to current and future cumulative effects on the six VECs, and the influence of the RMA on the current and future environmental sustainability (ES) of the six VECs. These two issues are addressed for the six VECs as follows:

- Relative to cumulative effects on the water quality VEC, Chapter 3 of the Cumulative Effects Assessment report in the Environmental Appendix denotes multiple governmental and private actions which are currently, and projected to continue to be contributors to cumulative water quality effects. Under current conditions, the negative water quality effects of the RMA are expected to be localized, short-term, and minor in their relative effects. However, continuing through the 60-year planning horizon for WOPC, lock closure and repair activities associated with cyclical maintenance and unscheduled repairs are expected to become more frequent and to require, on average, longer closures. The increased frequency and extent of repair activities would be the direct result of "wear and tear" of progressively aging lock components in the absence of proactive maintenance, rehabilitation, or replacement measures. The rate at which repair frequency and associated impacts would occur is directly related to traffic levels at each lock and/or to deterioration of materials due to aging. Further, the rate at which such traffic levels change is illustrated in the 5 traffic scenarios. As a

result, long-term effects from the RMA would produce increasing levels of negative impacts to water quality, thus contributing to a reduction of overall ES of the water quality VEC.

- Over the long term progression of increasingly frequent and complex repairs necessary to maintain an aging infrastructure, the potential occurrences of extraordinary or catastrophic events would be expected to increase. The cumulative effect of such events, as well as the impacts of emergency responses to such events, would be in addition the more predictable cumulative effects that are described in this section.

- In general, the long term impacts of the RMA will have similar effects for each of the VECs discussed here. Fish, mussels, and riparian resources would all experience increasing levels of negative impacts in proportion to the rate at which repair frequency and associated impacts would increase. Mussels are considered the most "at risk" VEC in this context and would thus be the most likely to exhibit declines in overall ES in response to the increased frequency and extent of reactive repair efforts to maintain an aging infrastructure.

- The cumulative impact to recreation interests of increasingly frequent and protracted periods of closure could result in declines in the use of certain portions of the river for recreational purposes. The decline of such recreational activities could result in economic losses to service providers in these areas and/or declines in property values or development potential of the riverfront.

- Health and safety risk factors would rise in direct proportion to the cumulative increase of repair activities. Such factors would be even more elevated whenever repair efforts must be undertaken in response to emergency conditions.

8.8 EVALUATION OF ENVIRONMENTAL SUSTAINABILITY MEASURES

8.8.1 Methodology

1. **Tables 8-6 and 8-7** in Section 8.5 identify a spectrum of program authorities by which the Corps, other state or federal agencies, or private organizations, may be able to initiate efforts to improve the environmental sustainability of certain Ohio River resources. **Table 8-6** compares a list of opportunities for enhancing Environmental Sustainability (ES) with existing authorities and related programs or responsibilities of the Corps. A category is also included for other agencies and NGOs, which is expanded upon in **Table 8-7** to address ES authorities of other federal agencies.

2. In this Section, the ES measures have been organized into 4 groups that reflect progressive levels of implementation complexity. This organization is independent of navigation alternatives. This grouping of ES measures is organized as follows:

- Group A: Measures for which authority already exists and which involve minimal costs. These measures would increase awareness of key VECs, focus on impact prevention, and could be implemented relatively quickly.

- Group B: Measures for which authority already exists, but which would require some costs for planning and/or construction. These measures focus on key VECs and incorporate restoration and enhancement.

- Group C: Measures for which some authority already exists, but new authority may be needed for some opportunities. Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement and the focus tends toward broader-level environmental needs.

- Group D: Measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement, and the focus tends toward broader-level environmental needs.

3. The potential effects of individual ES measures are summarized in **Table 8-10** for each of the major VECs. In this presentation, these enhancement opportunities have been organized according to the groupings described above. As authorities exist for measures in Groups A and B, the WOPC alternative for the purpose of environmental sustainability comprises those measures. This alternative is termed the "minimal plan" for ES. The other groups are included in WPC alternatives.

8.8.2 Sustainability in the Without-Project Condition

Based upon a comparison of the information presented in **Table 8-10** (potential effects of ES enhancement measures) and **Table 8-6** (existing authorities), the following generalizations can be made regarding potential implementation of the ES measures:

- Although the four measures in Group A are considered less difficult to implement than measures in the other groups, some obstacles to implementation must still be considered. As indicated in **Table 8-6**, although the marking of mooring areas in proximity to lock and dam projects may be within the Corps' authority, markings to control or redirect navigation on other parts of the river would require coordination with other agencies where such authorities reside (e.g., U.S. Coast Guard).

TABLE 8-10

POTENTIAL EFFECTS OF ES ENHANCEMENT MEASURES ON MAJOR VECS IN THE WITH PROJECT ALTERNATIVE

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Group A – Measures for which authority already exists. Such measures would involve minimal costs, increase awareness of key VECs, focus on impact prevention, and could be implemented quickly.						
Mark critical locations to prevent mooring near mussel beds or special shoreline areas.	+ + Reduces turbidity in areas near mussel beds where vessels previously moored.	Enhancement of mussel habitat benefits fish and other animals that feed on mussels.	+ + + Helps protect mussel beds from direct damage and scouring from tows and other vessels.	Helps protect sensitive shoreline areas vulnerable to loss of vegetation and erosion.	Decreases number of potential sites on river where conflict may occur between tows and recreational vessels.	+ Decreases vessel operations in shallow water areas.
Mark shallow mussel beds to reduce direct impacts of tow traffic.	+ + Similar to above action in reducing turbidity.	Similar to above action in enhancing mussel habitat for fish and other animals that feed on mussels.	+ + + Similar to above action in helping to protect mussel beds from direct damage and scouring from tows and other vessels.	Similar to above action in helping to protect sensitive shoreline areas vulnerable to loss of vegetation and erosion.	Clearly delineates areas recreational vessels should avoid.	+ Decreases vessel operations in shallow water areas.

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources.	+ + Similar to above action in reducing turbidity.	Helps protect spawning areas, other fish habitat and provides education on need to protect sensitive resources.	+ + + Helps protect mussel beds and other benthic habitat and provides education on need to protect sensitive resources.	Could also include important riparian resources, including wetlands and islands; Provides education on the value & protection of such resources.	Clearly delineates areas recreational vessels should avoid while also providing education on the value and protection of such resources.	+ Decreases vessel operations in shallow water areas.
Minimize catastrophic contamination events through reduction of spills, accidents, and improvement of spill response procedures.	+ Although several related measures are already in place, additional refinements would protect all aquatic resources from the immediate and long-term effects of contamination events.				+ Activities that protect or improve aquatic resources typically enhance recreation.	+ Reduction of incidents and improvement of responses would benefit navigation industries and the general public.
Group B – Measures for which authority already exists, but which would require some costs for planning and/or construction. Such measures focus on key VECs and incorporate restoration and enhancement.						

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Allow flows to mimic natural regimes including seasonal and extreme floods and droughts.	+ + Would reduce potential oxygen and thermal stratification upstream from L & Ds.	Would benefit typical river fishes by more closely approximating natural patterns.	+ + + Would benefit mussels adapted to rivers by more closely approximating natural patterns.	Would benefit native vegetation and seed banks dependent on seasonal patterns to sustain them.	Would enhance recreational experience of being on a river rather than the more lake-like environment currently provided by flow regimes.	- Low flows could increase groundings and spills. High flows would adversely affect navigation safety by increasing difficulty of maintaining vessel control.
Restore unique mainstem habitats such as canebrakes, river bluffs, and mussel beds.	+ + Would reduce erosion. Wetland restoration also would help filter runoff from upland areas.	Would help diversify fish habitat and feeding areas, particularly benefiting shoreline species.	+ + + Would enhance habitat for all mussel species and perhaps benefit specific endangered species.	Would enhance diversity of riparian habitats and also provide educational opportunities related to value of riparian resources.	Would enhance recreational experience by providing diverse shoreline habitats more typical of the pre-settlement river.	

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Protect tailwaters and provide structures to serve as refugia for fish.		+ Enhances habitat diversity and offers some protection from river traffic.	+ May simultaneously provide some protection for mussels.		+ Would make tailwater fishing more challenging and interesting and would attract more fish.	- In-stream structures in tailwaters could result in greater navigation hazards near Locks and Dams.
Create spawning shoals and other in-stream features to enhance habitat diversity in navigation pools.		+ Enhances habitat for reproduction and may diversify fish communities.	+ Enhanced fish habitat may also enhance mussel diversity and protection.		+ Would potentially make fishing more challenging and interesting and may attract more fish species.	+/- In-stream structures would need to be evaluated prior to placement to avoid creation of navigation hazards.
Identify and expand areas of submerged and emergent aquatic vegetation.	+ + Removes sediment and some contaminants.	Enhances fish habitat and protection.		+ + Creates a transition zone between riparian areas and open water that may provide habitat and food for some riparian species.	Visually enhances the recreational experience.	+ Aquatic macrophyte beds provide visible evidence of shallow water areas to be avoided by commercial and recreational traffic.

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Protect and manage mussel populations and their habitat on a site-specific basis.		+ Enhancement of mussel habitat benefits fish and other animals that feed on mussels.	+ May help restore species with specific habitat requirements.			
Control exotics, including minimization of existing populations and prevention of new introductions.	+ + Prevents adverse effects from exotics such as carp species.	Lowers potential competition with native fish species.	+ + + Increases sustainability of native mussels in several ways, including controlling predation by exotic fish species and competition from Zebra mussels.	Control of exotic plants improves health & sustainability of native riparian plant assemblages.	Maintains a more balanced ecosystem beneficial to fishing, birding, and wildlife watching.	+/- Could improve efficiency of navigation movements. Some control options (e.g., chemical) would be required to follow EPA label restrictions to ensure public protection.

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries.	+ + Reduces shoreline erosion and sediment inputs.	Enhances fish habitat and protection.	+ + + Islands enhance habitat and protection for native mussels and other benthic organisms. Side channels along islands are especially productive.	Enhances the many benefits of riparian areas and provides related educational opportunities.	Creates or enhances additional areas for birding, and wildlife watching.	
Maintain or restore tributary deltas and connections between rivers and embayments.	+ + Prevents siltation (and related turbidity) that can disconnect tributaries from the mainstem.	Restores important connections between tributaries and mainstem fish populations.	+ + + Restores important connections between tributaries and mainstem that facilitate recovery of mainstem mussel populations.	Enhances the transition zone between riparian areas and the mainstem and provides related educational opportunities.	Creates or enhances additional areas for fishing, birding, and wildlife watching.	

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Reforest lower reaches of tributaries to reduce siltation into embayments and mainstem.	+ Reduces turbidity and suspended solids in mainstem.	+ Enhances water clarity, especially for sight-feeding fishes.	+ + + Lowers siltation that interferes with mussels' filter feeding.	Enhances the transition zone between riparian areas and the mainstem and provides related educational opportunities.	Creates or enhances additional areas for fishing, birding, and wildlife watching.	
Group C – Measures for which some authority already exists, but new authority may be needed for some opportunities. These measures generally encompass broad descriptions of opportunity that may need refinement; planning and construction costs may be relatively high. The focus tends toward broader-level environmental needs.						
Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats.	+ Removes sediment, nutrients, and some contaminants.	+ Can create additional spawning and feeding habitat for certain species.		+ Restores natural patterns essential to sustaining riparian resources.	+ Creates or enhances additional areas for fishing, birding, and wildlife watching.	- Low flows could increase groundings and spills. High flows would adversely affect navigation safety by increasing difficulty of maintaining vessel control.

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Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Protect existing aquatic habitats, restore lost habitats and diminished resources.	+ + Restored wetlands help filter runoff.	Enhances, expands, and diversifies mainstem fish habitat.	+ + + Enhances and protects habitat for native mussels, including endangered species.	Enhances riparian areas and provides related educational opportunities.	Creates or enhances additional areas for fishing, birding, and wildlife watching .	
Reintroduce native fauna and expand the range and populations of native fauna from reduced levels.		+ Beneficial in restoring the wide variety of fish species endemic to the Ohio River	+ + + Beneficial in restoring the wide variety of mussel species endemic to the Ohio River	Enhances riparian areas and provides related educational opportunities.	Creates or enhances opportunities for fishing, birding, and wildlife watching.	
Reconnect and restore streams with floodplains on the mainstem and tributaries.	+ + Restores hydrological connections beneficial to water quality.	Restores important connections between floodplains and mainstem fish populations.	+ + + May restore hydrological connections beneficial to mussels.	Enhances riparian areas and provides related educational opportunities.	Creates or enhances opportunities for fishing, birding, and wildlife watching.	

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	Fish	Mussels	Riparian Resources	Recreation	Health and Safety
Restore wetlands in upper ends of embayments to reduce siltation and create fish and wildlife habitat.	+ + Restored wetlands help filter runoff.	Provides high quality fish spawning and nursery areas.	+ + + May facilitate connections between mussel populations.	Enhances riparian areas and provides related educational opportunities.	Creates or enhances opportunities for fishing, birding, and wildlife watching.	
Group D -- Measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Such measures may require more extensive planning and implementation costs. These measures focus on broader-level environmental needs.						
Enhance fish passage around or through dams.		+ Aids riverwide distribution of migratory and other fish species.	+ Aids riverwide distribution of fish hosts critical to mussel success.		+ Promotes a wider distribution of angler preferred species throughout the river.	- Attracting flows into fish passage facilities must be evaluated to ensure flows do not adversely affect vessel entry and exit of lock chambers and approaches.

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Dismantle unneeded federal tributary dams.	+ + Promotes flowing water (lotic) conditions that enhance oxygenation and sediment transport.	Enhances movement of fish within tributaries and between tributaries and mainstem.	+ + + Enhances mussel distribution within tributaries and between tributaries and mainstem.	May allow for vegetation and wildlife habitat restoration near former dams.	May create new riffles and pools for fishing, canoeing and new shorelines for parks and trails.	+/- Could provide safety harbors. May create opportunities for vessel entry into shallow waters.
Dismantle unneeded non-federal tributary dams.	+ + Promotes flowing water (lotic) conditions that enhance oxygenation and sediment transport.	Enhances movement of fish within tributaries and between tributaries and mainstem.	+ + + Enhances mussel distribution within tributaries and between tributaries and mainstem	May allow for vegetation and wildlife habitat restoration near former dams.	May create new riffles and pools for fishing canoeing and new shorelines for parks and trails.	+/- Could provide safety harbors. May create opportunities for vessel entry into shallow waters.

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Reduce bacterial contamination from combined sewer overflows.	+ + Direct beneficial effects to alleviate the river's most challenging water quality problem.	Improved water quality directly benefits fish.	+ + Improved water quality directly benefits native mussels.	Direct beneficial effects in riparian areas where CSOs are located.	+ Improves conditions for those fishing, canoeing, and bird and wildlife watching.	+ Reduces bacterial contamination and increases safety of water contact.
Address point and non-point sources affecting aquatic nutrient balance.	+ + Directly benefits water quality by reducing nutrient levels and other substances in effluents and runoff.	Improved water quality directly benefits fish.	+ + + Improved water quality directly benefits native mussels.	Water quality improvements enhance experience for all types of river and shoreline resources.	Water quality improvements enhance experience for all types of river and shoreline recreation.	

Opportunities for ES Enhancement	Impacts on Major VECS					
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	**Health and Safety**
Continue remediation of CERCLA, brownfields, and other contaminated sites.	+ + Directly benefits groundwater and surface water quality where contamination has occurred. Reduces sediment contamination	Improved water quality directly benefits fish in streams on site and in localized river reaches.	+ + + Improved water quality directly benefits mussels in streams on site and in localized river reaches.	Offers revegetation and habitat restoration and related educational opportunities.	Over time, may provide areas for parks, playgrounds, trails, and wildlife watching.	+ Would reduce risks of exposure to contamination and potential release of contaminants to the aquatic environment.
Conduct economic evaluation of watershed functions and benefits.	+ + Emphasizes importance of good water quality to ecological sustainability, public health and economic viability.	Could highlight the importance of fish in a watershed's ecological balance and contribution to economic benefits of recreation.	+ + + Could highlight the importance of mussels in a watershed's ecological balance.	Could highlight the importance of high quality riparian resources in a watershed's ecological balance and in recreational and residential land values.	Could highlight the opportunities high quality ecological systems offer for recreation and enhanced value of recreation economics.	+ Could lead to reduction of contamination of the aquatic environment stemming from the watershed.

- This group of sustainability measures will be more successful when added to the Reasonable and Prudent Measures identified through consultation under Section 7 of the Endangered Species Act. These measures would be incorporated into normal Operations and Maintenance.

- Adding the location of sensitive resources to navigation charts with a discussion of the need to avoid impacts to such resources could reach a wider audience of recreationists in addition to navigation interests. Such an approach could also be focused on a wider spectrum of sensitive resources. In 2003, a special edition of Ohio River Navigation Charts was issued commemorating the Lewis and Clark expedition; a similar special edition could be issued celebrating the recovery of aquatic and riparian resources and addressing ongoing protection needs.

- While much progress has been made over the past 30 years in the areas of spill reduction, prevention and response, some additional progress could be realized through the coordinated efforts of multiple agencies in conjunction with navigation and the other industrial interests associated with such events. Additional progress is also needed to compensate for the effects of continued (albeit gradual) concentrations of such activities on or near the river. Implementation of group A measures would have positive effects on health and Safety through reducing the likelihood of vessel operations in sensitive shallow water areas and lessening the potential for contamination of the aquatic environment.

- The ten measures included in Group B constitute approaches that focus more directly on enhancement or restoration of the key VECs, as opposed to the focus on increased awareness and impact prevention of Group A. The Corps possesses at least some form of authorization for all measures in this group. Regardless of where the primary authorization for such actions resides, these measures will require some coordination and cooperation among federal and state agencies, navigation interests, recreationists, and other stakeholders.

- Allowing flows to mimic natural regimes, including floods and droughts, could be a very cost effective approach to environmental restoration by simply restoring the most constrained life-cycle aspects of a broad spectrum of native aquatic and riparian species. This measure also illustrates the nexus of the traditional Corps role as the primary federal agency responsible for managing an expanding range of water resource goals (flood control, navigation, recreation, and restoration) and the potential benefits of applying water-engineering solutions to the goals of restoring diverse and sustainable native aquatic/riparian communities.

- Some measures in group B (i.e., allowing flows to mimic more natural extremes) could adversely impact Health and Safety by increasing risks to vessel operations. Placement of instream structures must be carefully evaluated to avoid increasing risks to vessel operations, while establishment of aquatic macrophyte beds would provide visible evidence of shallow water areas and would warn boaters of

potential hazards. Controlling exotics could improve vessel efficiencies by reducing weight and drag from attached zebra mussels. Conversely, control methods, especially chemical and some physical, would require considerable exercise of caution to prevent creating other Health and Safety problems.

- The Mainstem is not only affected by activities along its shores and within its floodplain, but also by land use practices and activity within the basin. These effects often reach the river via the tributaries. A holistic approach to sustainability, therefore, needs a basin perspective. The Ohio River Basin Comprehensive Study would provide the Corps with the opportunity to review basin-wide water resources.

- Many of the other recommendations in Group B would benefit from the ability to manage flow regimes as described above. Restoration of unique habitats, more productive tailwaters, enhanced aquatic habitat diversity, aquatic vegetation, riparian habitat diversity, tributary-embayment-mainstem connectivity, and riparian reforestation are all functionally linked to the hydrologic cycles of riverine systems. The ultimate effectiveness of this spectrum of recommendations would lend itself well to experimental approaches designed to adjust management approaches in response to results experienced.

- The ORMSS cumulative effects studies (see Section 6.4.1 of this report) identified several specific resources that are most at risk with respect to sustainability under current and foreseeable future conditions on the Ohio River mainstem. These at risk resources are included in Group B recommendations addressing mussel populations and habitat, islands, aquatic vegetation, and riparian habitat diversity.

- The control of exotic species that are presently established in the Ohio River mainstem may require strategies of direct intervention, either to reduce numbers of exotics or to protect sensitive resources from damage. This may be especially important during the early years of invasion, when exotic populations and consequent impacts tend to peak. Control of exotics may also benefit somewhat from management approaches that restore or mimic natural regimes. To the extent that exotics compete with natives for food, spawning habitat, and other needs; the restoration of natural habitats and hydrologic conditions should favor the natives. Monitoring of fish populations in the Ohio River suggests, at least anecdotally, that native suckers are recovering, in numbers and diversity, at the expense of the non-native common carp.

- Preventing new introductions of exotic species, or constraining the expansion of existing invasive populations requires a broader spectrum of authorities, inter-agency cooperation, and regulatory enforcement. Shipping, aquaculture, landscaping, and immigration have been the source of past introductions and will continue to contribute new introductions so long as the source practices (e.g., lax regulation of bilge water management) continue.

- Group C includes five measures that are generally similar in concept and objectives to the Group B recommendations, but less specifically focused. Implementation of these measures would require relatively more refinement or specification, with a corresponding increase in the degree of cooperation and coordination required among stakeholders. The Corps possesses at least some form of authorization for all measures in this group. Measures included in group C are in the WPC rather than the WOPC.

- The most specifically focused recommendation in this group addresses the restoration of wetlands in the upper ends of embayments. Wetlands are one of the at-risk resources identified in the cumulative effects analysis (see Section 6.4.1) and embayments generally occupy only a small proportion of the area of each pool on the river. As illustrated in **Table 8-10**, wetlands restoration could generate a broad spectrum of direct and secondary benefits. However, competing demands exist for access to and use of embayments, especially in the more populated pools, contributing to the potential complexity of collaborative efforts to implement this recommendation. Increasing seasonal flooding could create additional risks to vessels due to associated high flows.

- The seven recommendations in Group D include opportunities that require new authorities or are primarily addressed through authorities of other agencies. The Corps has no existing authority in two of these measures and relatively limited authority in several others. To the extent that lack of authorization and/or funding constraints limits these opportunities, implementation is more likely to be realized under a WPC that addresses such constraints.

- Three of the Group D recommendations involve actions (fish passage, dismantling federal or non-federal dams) that would likely require participation by the Corps. Such measures could benefit Health and Safety through provision of safety harbors; however, dam removal could create opportunities for vessels to be operated in shallow water. Fish passage suggests an opportunity that could be designed into future renovations or modernizations of locks on the Ohio mainstem. Fish passage designs would require careful evaluation to ensure flows are designed to attract target fish species without affecting vessel operations during lock entry and exit. Dismantling tributary dams represents an expansion of the environmental restoration focus beyond the mainstem and illustrates the potential ecosystem sustainability benefits of recognizing the interconnectedness of the mainstem and its tributaries. Reducing sources of bacterialcontamination and restoration/reuse of previously used sites would benefit Health and Safety by reducing public exposure and lessening contamination potential in the aquatic environment. This expanded focus could also be applied to several of the recommendations presented in Groups B and C.

8.9 REMAINING PROBLEMS AND OPPORTUNITIES

8.9.1 Commercial Navigation Delays

From **Table 8-8**, the economic benefits to commercial waterway users are eroded to varying degrees depending upon traffic scenario, but range from $76 to $123 million **annually** due to delays caused by congestion at the locks. A portion of these congestion costs are due directly to main chamber closures required to repair failed components. It may be possible to reduce the congestion costs through either proactive maintenance or extending the 600' auxiliary locks or construction of new locks at EDM. Of course the trade-off would be increased Federal maintenance and construction costs. These alternatives are formulated and analyzed in the With Project Condition in Sections 9 and 10.

8.9.2 Environmental Considerations

The recommendations for achieving Environmental Sustainability on the Ohio River, presented in **Tables 8-6 and 8-10**, address what needs to be done. However, the discussion in this Section does not go into detail regarding how to achieve these goals. The ES conferences that resulted in these recommendations did present some conclusions regarding how to proceed. Following are some brief notes regarding such recommendations:

- Maintain and expand existing means of interagency communication and collaboration.
  - Annual or bi-annual restoration practitioner's conferences
  - Maintain/expand email network of ORMSS IWG and maintain communications within this group
  - Continue to convene IWG meetings as needed

- Implement the Ecosystem Restoration Program, which is presently authorized but unfunded. NOTE: Because the Ohio River Ecosystem Restoration Program has yet to receive Congressional appropriations, the program is now a candidate for de-authorization.
  - Funding is needed to initiate program planning, develop ES project review procedures, and solicit ES project proposals
  - Seek authorization to expand ERP to include ES projects on tributaries of the Ohio River
  - Seek authorization to include nongovernmental organizations as local, cost sharing project sponsors

Recommendations for implementing a strategy to achieve desired ES outcomes for the Ohio River are presented in Section 10.7.

SECTION 9
FORMULATION OF ALTERNATIVE SYSTEM INVESTMENT PLANS (ACTION ALTERNATIVES UNDER NEPA)

This section discusses the development and screening of improvement plans for Ohio River facilities required to address the problems and needs identified in the without-project condition assessments. Investment plans are defined by the timing and specification of proactive maintenance and/or modernization projects at each lock and dam facility and are evaluated for each of the traffic forecast scenarios described in Section 8.2. Measures considered and carried forward for navigation alternatives are presented in Sections 9.2 and 9.3 and ecosystem measures are addressed in Section 9.4. Navigation and ecosystem sustainability components are addressed separately in this Section for clarity. Alternatives for navigation are formulated in Section 9.6. Environmental alternatives are formulated to address problems related to sustainability of Ohio River Environmental Ecological Components. Formulation of ecosystem sustainability alternatives is provided in Section 9.8. Alternatives are evaluated in Section 10. This section completes the third step of the plan formulation process addressing With-Project plans (Section 2.4.3).

9.1 GENERAL METHODOLOGY AND GUIDELINES

1. A broad range of improvement measures were identified to address economic and environmental concerns at all Ohio River locks and dams. All options that have practical application, reasonable development costs and significant beneficial economic and environmental effects were carried forward for more detailed evaluations. The detailed evaluations considered navigation and ecosystem benefits and associated environmental or ecosystem impacts. SIPs were developed by layering improvement measures at each project through time after assessing the system-wide benefits and costs. Refinements were considered in an iterative fashion until improvements were optimized. At that point the final or best SIP was identified for the corresponding traffic scenario.

2. The process used to formulate alternatives is the same used in evaluating the reactive maintenance alternative (the WOPC). Evaluations were made for the same five traffic scenarios. Although the basic scenarios are the same, the "induced traffic" expected to be brought about by larger locks at Emsworth, Dashields and Montgomery (EDM) is be considered in the evaluation. Induced traffic is the subject of subsection 9.2. As with the WOPC, maintenance, operational efficiency and low-cost structural measures

are identified, except that options may now include investment decisions involving proactive maintenance. The last type of measure is capacity-increasing improvements at all locks and dams, including lock extensions and new locks, for which Congressional Authorization would be required for implementation.

9.2 MAINTENANCE, OPERATIONAL EFFICIENCY AND LOW-COST MEASURES CONSIDERED

9.2.1 Reactive Maintenance Measures

All maintenance measures considered for the Reactive Maintenance (WOPC) and described in Sections 8.3.1 and 8.3.2, namely routine maintenance, cyclical maintenance, unscheduled repair of failed components, and full implementation of the MGQCS will also be assessed in the formulation of WPC plans.

9.2.2 Proactive Maintenance Measures

Proactive maintenance measures include scheduled repairs or replacement of major lock components. Two such measures are considered, work on individual components and major rehabilitation usually involving work on multiple components.

9.2.2.1 Scheduled Component Replacement

As the projects age (most of the projects will be nearly 100 years old by the year 2060), many of the major components will need to be replaced in order to keep the chamber usable for passing traffic. Past experience on Ohio River system locks has indicated that items such as miter gates, culvert valves, etc., tend to need replacement, called advanced maintenance in this report, after about 40 to 70 years of operation. The timing of advanced maintenance varies depending upon site-specific conditions, original design parameters, traffic levels, etc.

9.2.2.2 Major Rehabilitation

As discussed in Section 6, major rehabilitation (MR) involves major component replacement and or repair work that costs more than a monetary threshold ($10.6 million as of Fiscal Year 2005) that is adjusted annually. Additional details on requirements of MR projects are provided in Engineering Pamphlet (EP) 1130-2-500.

9.2.2.3 Assessment of Maintenance Measures

1. Routine maintenance, cyclical maintenance, and unscheduled lock repairs are required to operate a viable navigation system and must be carried forward. The two additional proactive maintenance measures considered are ways to more efficiently operate and maintain this system, and are also carried forward in the WPC. The goal of

proactive maintenance is to avoid unexpected component failures and the potential for long lock closures and large navigation delay costs.

2. One restriction on major rehabilitation is considered necessary at this stage of study. Future major rehabilitations of the EDM lock walls to address stability issues with additional rock anchors is not considered feasible. This is due to the presence of significant zones of deteriorated and cracked concrete, which are located beneath 10 to 14 inch thick concrete overlays that were placed in the late 1980's. The lock wall anchoring systems placed during these previous rehabilitations lie within zones of (original non-air entrained) concrete that have been characterized through testing to be in an extensive to moderate degree of deterioration. Any rehabilitative measures to further anchor the lock walls at these facilities would require extensive replacement of significant zones of deteriorated concrete to allow additional anchors to be placed. As much as 3-feet of concrete would need to be removed from the faces of some walls (Emsworth River Wall). Restoring the effectiveness of the existing anchors is not possible since they are embedded in a continuous shroud of grout and buried beneath the concrete overlays. It is also noted that due to the deteriorated state of concrete beneath the concrete overlay, installation of additional anchors may not be completely effective or could even further damage the structural integrity of the walls due to the deteriorated state of the concrete. Therefore, total replacement of the walls is the only major rehabilitation alternative formulated to restore long-term wall stability. Such reconstruction would ultimately create significant impacts to river traffic. From an economic perspective, such reconstruction is not practical due to long chamber closure times and the associated navigation delay costs that would be required. Therefore, major rehabilitation of EDM was screened from the analysis as a maintenance option in the WPC

3. Full implementation of the MGQCS by adding spare gates and storage facilities would require a considerable planning and investment and is not considered feasible in the WPC. With-project measures carried forward include the replacement of lock miter gates before failure but do not evaluate any benefit of spare gates. This is considered sufficient for this study. However, the capability reducing times to repair and replace gates with the Shreve during proactive maintenance on the gates is in all WPC alternatives. Gates are liftable so that if an emergency were to arise in a main chamber, the Corps could pull a set of auxiliary gates out to serve as a "spare" set of gates for the main chamber as a last resort. Economic evaluations reflect these capabilities.

4. Maintenance measures carried further and those dropped from the analysis are shown in **Table 9-1**.

TABLE 9.1
Maintenance Measures Carried Forward and Dropped From Consideration In WPC

Summary of Maintenance Measures Carried Forward in WPC: Routine Maintenance Cyclical Maintenance Unscheduled Repairs Scheduled Component Replacement Capability to Lift Lock Gates Major Rehabilitation (Other than EDM) **Maintenance Measures Dropped From Consideration in WPC:** Spare Gates for Miter Gate Quick Changeout System Major Rehabilitation at EDM

9.2.2.4 Cost Estimation for Maintenance Measures Carried Forward

1. Pertinent considerations for future implementation costs for measures retained are discussed below. Costs for routine and cyclic maintenance and unscheduled repairs and replacements are as described previously for the reactive maintenance alternative. The cost for a scheduled replacement of a component is typically lower than for an unscheduled replacement of the same component required after a failure in the reactive maintenance alternative. Another consideration for scheduled or cyclic maintenance cost of lock components with proactive maintenance is that the frequency and cost of this maintenance depends in part on physical condition of the components as well as on the intensity of use. Less reliable components require more intensive and frequent levels of this maintenance in an effort to keep them in service longer than may be justified. Component replacement introduces new equipment for which this cyclic maintenance can be relaxed somewhat and thereby reduce these cyclic maintenance costs somewhat compared to these costs in the reactive maintenance alternative.

2. Major Rehabilitations for either the main or auxiliary chambers were determined based on the timing of scheduled component replacements. It may prove more beneficial to combine replacement of several of the components together in one or two closures. Such bundling may result in a cost savings due to "economies of scale" by eliminating duplicative efforts and reducing the duration of work activities (and even more importantly the total duration of any main chamber closure) compared to performing the same work at different times. Replacing multiple components at the same time would only require one dewatering of the main chamber and the associated "mobilization" comprised of all activities required to prepare for the job. On the other hand, completing the component replacements at different times would require two or more mobilizations and dewaterings. The duration of the bundled activities could be as short as required for the most involved replacement work, whereas the duration would be the sum of the

multiple durations if performed separately. Another potential difference could occur if none of the component replacements meet the requirements of the MR program but the bundling effort does. In that case, bundling the work would require an additional effort of a Major Rehabilitation Evaluation Report. Funding each component replacement would be from the Federal Operations and Maintenance account, whereas the MR would be funded 50 percent from the Federal Construction General account and 50 percent from the Inland Waterway Trust Fund. The latter funding arrangement would be required to realize the overall (repair + delay to navigation) cost savings.

3. Costs for the potential bundling of components was estimated to be 80 percent of the sum of the individual component replacement costs. If the cost of this work exceeds the threshold, the work would qualify as a major rehabilitation project. The duration of any main or auxiliary chamber rehabilitation varied and depended on the components included in the MR project.

9.2.3 Operational Efficiency and Low Cost Structural Measures

All operational efficiency measures currently implemented and carried forward for the WOPC as discussed in Section 8.4 will also be considered for the WPC. These measures include N-up/N-down lockage policy, helper boats operated by industry, coordination between the Corps and industry prior to any extended main chamber closure, existing tow haulage units and mooring cells, industry adjustments during main chamber closures, and various other miscellaneous measures. Two additional measures considered for WPC plans are classified as "demand management" measures, congestion fees and Corps-imposed traffic scheduling. As cited by the Transportation Research Board's Committee for the Study of Freight Capacity for the Next Century, traffic demand management is a means of forestalling expensive capital investments as these policies encourage shippers to shift to other arrival schedule, route, mode and/or product source options. Demand management measures could therefore reduce system delays. These measures are summarized below. See **Attachment 5 of the Economics Appendix** for a more detailed discussion of Traffic Management measures.

9.2.3.1. Congestion Fees

A lockage fee could cause shippers to shift to either alternative transportation modes or markets, thereby reducing the amount of lock congestion for all remaining waterway shipments. Thus it serves to ration lock use to those movements with the highest transportation savings. The result would be an increase in total rate savings net of delay costs for shippers that continue to use the waterway. A congestion lockage fee could reduce arrivals (queues) and, therefore, delay costs at a congested lock during closure.

9.2.3.2 Corps-Imposed Tow Scheduling

Price-related traffic demand management measures are not currently used on the mainstem. Corps-imposed tow scheduling is one example. Locks nearing their practical capacity limits can benefit from a traffic-scheduling program that assigns tow arrival times. The goal of such a scheduling program is to reduce delays and their associated costs. Using lock scheduling to reduce delays that occur due to random arrivals during the normal course of using the Ohio River mainstem is not currently practiced and is generally opposed to by the shipping industry.

9.2.3.3 Assessment of Operational Efficiency and Low Cost Structural Measures in With Project Condition

All operational and low cost structural measures carried forward for the WOPC are retained for evaluation in the WPC due to their proven effectiveness.

Congestion Fees

Although a detailed analysis of congestion fees has not been conducted for this study, a general analysis of traffic management alternatives was completed (see **Attachment 5 Traffic Management Analysis** of the **Economics Appendix**) and some preliminary determinations have been made. A congestion lockage fee could be used to influence shipping decisions for shippers with marginal transportation rate savings. Congestion fees are generally considered to be an alternative to providing additional capacity at a public facility that is characterized by persistent delays and queues. In the case of the Ohio River mainstem locks and dams, congestion is associated with periodic closures of the main chambers rather than persistent congestion due to a system approaching capacity. The best way to manage these short-term and periodic episodes of congestion is with temporary nonstructural management measures such as industry self-help and N-up/N-down lockage policies. The implementation of long-term congestion fees based on short-term and periodic congestion would tend to distort the transportation practices of shippers in an uneconomical way. Congestion fees are not carried forward as part of the SIP WPC because they do not address the maintenance and structural investment needs of the mainstem. The Navigation Economic Technologies (NETS)[1] is conducting research on this measure and, based on their findings, this measure could be reconsidered in subsequent studies.

[1] Each NETS research effort includes a work team consisting of Corps personnel and outside experts from the academic community, other agencies, and other interested parties. Each research activity also is peer-reviewed by a team of independent academic experts. For more information, see the NETS web site http://www.corpsnets.us/index.html.

Corps-Imposed Traffic Scheduling

A preliminary research effort into the physical practicality and economic feasibility of lock scheduling is underway as part of this study. Results-to-date are found in **Attachment 5 Traffic Management** Analysis of the **Economics Appendix**. Evaluation of lock scheduling was based on limited one-project simulation intended to verify the random nature of arrivals and the effects on delays given an equal time interval between tow arrivals and assuming a lock open at all times. Results indicated a reduction on average of less than one hour per tow. Expansion of this concept to a series of tows would require that tows adjust speeds and schedule departures to accommodate multiple scheduled arrival times. It is expected that the average reduction in delays over a series of locks would be lower than for a single arrival situation. This result indicates that lockage scheduling is unlikely to be an effective solution to transportation problems caused by delays on the navigation system. The NETS is also studying traffic scheduling and based on their findings, this measure could be considered in subsequent studies.

Summary

None of the measures considered that are not currently implemented are retained in the WPC. **Table 9-2** summarizes the results of this assessment.

TABLE 9-2
Operational and Low Cost Structural Measures Carried Forward and Dropped From Consideration in WPC

Operational and Low-Cost Structural Measures Carried Forward:	
Operational	Low Cost Structural
N-up/N-Down Lockage Policy	Tow Haulage
Advanced Notice of Main Chamber Closures	Mooring Cells
Adjustment of Shipment Schedules by Industry	Temporary Mooring Facilities During Main Chamber Closures
Industry Self Help	
Operational and Low-Cost Structural Measures Dropped From Analysis:	
Operational	Low Cost Structural
Traffic Scheduling	Guide/Guard Wall Extensions
Congestion Fees	
Traffic Scheduling By Corps	

9.2.4 Cost Estimation for Operational and Low Cost Structural Measures Carried Forward

As for the WOPC, costs for these measures if appropriate are based on actual implementation or historic costs.

9.3 LOCK MODERNIZATION MEASURES CONSIDERED

9.3.1 Locks and Dams at New Sites

This measure would involve construction of locks and dam(s) at a new site and could be applied to address all problems at any existing facility, in effect being a replacement project. A new project could be constructed either upstream or downstream from the present facility. If constructed upstream, the elevation of a river segment would be lowered; resulting in a shallow channel between the old and new sites. Dredging to maintain the authorized navigation channel depth would be required. If constructed downstream, the elevation of a river segment would be raised. In either case, relocation or adjustment of facilities such as outfalls, boat ramps, and submarine crossings (pipelines) may be needed to adjust to the new pool elevations. Such costs would increase total project costs. Beneficial effects include provision of greater lock capacity and reduction of maintenance costs compared to the older project.

9.3.2 Third Locks

Another option considered for all facilities is the construction of a third lock, either landward of the land chamber or riverward of the river chamber. An additional lock chamber at any site would increase the capacity to process traffic and thereby reduce traffic delays.

9.3.3 Lock Extensions

This measure includes extensions of the lock chambers that are less than 1200' in length to increase the capacity of existing projects.

9.3.4 New Locks

Construction of one or two new and larger locks at any site could replace any of the existing small locks at EDM or small auxiliary locks at other sites to increase lock capacity.

9.3.5 Assessment of Lock Modernization Measures

Locks and Dams at New Sites

Locks and dams at new sites are not considered applicable for consideration in this analysis. The associated dredging and disposal requirements could have serious negative environmental and social ramifications. A downstream project would raise the pool between the old and new sites. This would not require dredging, but could submerge or otherwise adversely impact shore side facilities designed for existing pool levels, requiring costs to adjust such facilities. The construction cost of a new project at any location is excessive when compared to measures that increase capacity at existing sites as described below. The adverse environmental and social impacts, including facility adjustment costs that would be incurred by non-Federal entities, of such a major project would be significant. Therefore, this measure has been dropped from further consideration.

Third Locks

A third lock would increase a project's capacity to move traffic and thereby increase total system benefits for any given traffic level. However, this option would incur considerable cost in light of other available measures described below, while incurring considerable environmental impacts owing to major land disturbances and excavation in the case of new landward chamber. This measure has been dropped from consideration.

Lock Extensions

1. Lock extensions are an alternative way to increase a project's capacity to pass traffic and thereby increase total system benefits, but is best suited for small locks that are in good physical condition. Due to the age and small size of the locks at Emsworth, Dashields, and Montgomery, extensions of these auxiliaries is not a practical option. Extension of all 600' long auxiliary chambers downstream of Montgomery are carried further. Extensions of 200', 400' and the maximum extent of 600' have been considered. The data in **Table 9-3** show the predominance of tow sizes through all relevant projects in recent times that were greater than 1,000', therefore 600' extensions are the only measure considered appropriate for the Ohio River. As expected, the percentage of tows greater than 1,000' increases as one proceeds downstream, ranging from nearly 2 in 3 at Myers to 3 in 10 at New Cumberland. On the premise that tow size distributions stay about the same during closures of the main chamber as they are during normal operations, this means that a significant percentage of tows would be required to double cut through locks of 1,000' or less. Based on this consideration, extensions of less than 600' for auxiliary chambers on the Ohio River are not considered appropriate. Six hundred foot extensions of these auxiliary chambers would substantially reduce delays during closures of a 1200'x110 chamber, so this measure will be considered for all WPC plans.

TABLE 9-3
Percentage of Tows Greater Than 1000' in Length
Ohio River Locks and Dams Below Montgomery L/D
1998-2002

	% Tows Greater Than 1000' In Length				
	1998	1999	2000	2001	2002
Myers	65.6%	66.2%	68.1%	68.8%	65.5%
Newburgh	58.4%	59.6%	61.2%	61.9%	61.0%
Cannelton	55.4%	57.3%	58.5%	59.3%	58.2%
McAlpine	52.0%	51.1%	49.9%	49.3%	47.3%
Markland	50.7%	52.0%	50.7%	54.4%	51.7%
Meldahl	61.8%	62.8%	63.6%	67.2%	63.4%
Greenup	56.3%	58.0%	60.9%	63.5%	60.6%
Byrd	52.7%	54.4%	55.0%	59.1%	55.8%
Racine	53.1%	54.7%	53.0%	56.9%	57.5%
Belleville	52.8%	56.9%	56.2%	60.1%	60.9%
Willow Island	48.8%	50.5%	52.1%	55.9%	57.6%
Hannibal	46.3%	47.5%	49.4%	55.3%	54.4%
Pike Island	34.8%	34.2%	36.3%	38.5%	38.1%
New Cumberland	30.7%	28.4%	29.6%	31.8%	35.5%

2. A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Lock extension plans were evaluated at Meldahl, Markland, Cannelton and Newburgh. (Improvements at all of these sites, in conjunction with the authorized projects at Greenup and Myers, would result in all projects on the lower 641 miles of the Ohio River mainstem having twin 1200'x110' locks.) Based on traffic forecasts, these projects were considered most likely in need of additional auxiliary capacity. As these projects already have a 1200' main chamber, extending the auxiliary to 1200' is not expected to induce any additional traffic onto the river.

New Locks

1. Construction of new locks to replace small locks is another way to increase a project's capacity, but is only considered at EDM due to the age and under-sized locks. Extensions of small auxiliary chambers are the better plan at all other sites. At EDM, the auxiliary chamber would be replaced in any plan, but the old main chambers could either be retained and patched up for use as auxiliary chambers or replaced. For this study, it was determined that the old chambers could be retained since the new river chamber could then serve as the new main chamber. Lock sizes considered for the new river chamber at any of these sites was 110' in width and either 600' or 1200' in length. Widths less than 110' are not practical at EDM in light of the 110' wide chambers downstream on the Ohio River and the 110' wide (and 720' long) chamber upstream at Braddock Locks and Dam on the Monongahela River, the primary navigation artery to the Upper Ohio River. The specific improvements developed at each site are shown in **Table 9-4**.

TABLE 9-4
Improvements Considered For Emsworth, Dashields, and Montgomery

Land Chamber	River Chamber
Maintain and Use as Auxiliary	New 110' x 600'
Maintain and Use as Auxiliary	New 110' x 1200'

2. Since the largest existing lock at these sites is 600 feet long, these sites present a constraint on system traffic demand. Therefore, introducing a 1200-foot lock at all three of these sites was analyzed for the potential to induce additional traffic.

3. In light of this situation, a special traffic survey was conducted with the purpose of identifying traffic that could be induced by waterway improvements on the Upper Ohio segment. This survey was conducted by analysts at TVA. Details of the process and results are provided in the Economics Appendix. As a result of these efforts, 11 potential commodity movements totaling 954,000 tons were identified that were considered to be representative of the type and volume that could be expected to be induced annually by improvements (construction of 1200'x110' locks at all three projects) on the Upper Ohio. A listing of this potential traffic is provided in **Table 9-5**.

TABLE 9-5

Potential Annual Induced Traffic With Larger Locks At Emsworth, Dashields, and Montgomery

Commodity Tonnage

Coal & Coke	25,000
Chemicals	80,000
Ores & Minerals	40,000
Iron & Steel	379,000
All Other	430,000
TOTAL	954,000

5. For any plan that does not involve construction of 1200' locks at these three projects, the traffic forecasts will be the same as the respective WOPC forecast.

Summary

Lock modernization measures carried further and those dropped from the analysis are shown in **Table 9-6**.

TABLE 9-6
Lock Modernization Measures Carried Forward and Dropped From Consideration in WPC

Lock Modernization Measures Carried Forward in WPC:
600' Extensions of all 600'x110' Auxiliary Locks – Meldahl, Markland, Cannelton and Newburgh only.
New 600'x110' or New 1200'x110' Lock To Replace 360'x56'Lock & Repair Existing 600'x110' Lock- Emsworth, Dashields, and Montgomery only.
Lock Modernization Measures Dropped From Consideration in WPC:
Extensions less then 600' for any 600'x110' Auxiliary Lock
Third Locks (At Any Project)
Lengths of New Locks at EDM between 600' and 1200'
Widths of New Locks at EDM Less Than 110'

9.3.6 Cost Estimation for Lock Modernization Measures Carried Forward

1. The level of detail in terms of designs and cost estimates is only conceptual because this document is not authorizing any major project improvements. The large-scale capacity improvement designs primarily involved either new lock chambers or extensions of the existing lock chamber to a nominal length of 1200 feet. Costs for new 110'x600' and 110'x1200' lock chambers at EDM were estimated based on Conceptual Design Reports prepared by INCA (1997, 1998, see Table 3-1). Conceptual designs and costs developed up to this point incorporate "float-in" technology that eliminates the use of cofferdams. This strategy will be reconsidered along with traditional "in-the-dry" lock construction, involving the use of cofferdams, during subsequent Feasibility-level studies to ensure the most cost efficient construction method is identified. In summary, the costs for all modernization strategies considered at EDM are summarized in **Tables 9-7 through 9-9**.

TABLE 9-7
Emsworth Lock Modernization Measure Costs

River Chamber	Land Chamber	Total Cost Rounded
New Lock 600' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$250,000,000
New Lock 1200' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$290,000,000

TABLE 9-8
Dashields Lock Modernization Alternative Costs

River Chamber	Land Chamber	Total Cost Rounded
New Lock 600' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$210,000,000
New Lock 1200' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$275,000,000

TABLE 9-9
Montgomery Lock Modernization Alternative Costs

River Chamber	Land Chamber	Total Cost Rounded
New Lock 600' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$240,000,000
New Lock 1200' x 110'	Repair Land Chamber To Serve As Future Auxiliary Chamber	$325,000,000

2. In general, there are two types of projects on the Ohio River where the main chamber is 1200-ft and the auxiliary chamber is 600-ft. The first is representative of many of the projects on the lower river (Newburgh) where there are 6 laterals for filling and emptying the existing auxiliary lock chamber. For these types of projects, extension costs will be determined with the conceptual designs and costs for Newburgh. The other type is similar to the Meldahl project where higher pool differentials required 11 laterals to fill and empty the lock chamber. Extension costs of similar projects will be determined with conceptual designs and costs for Meldahl..

3. As described in the Engineering Appendix, three cost estimates were developed for Newburgh and for Meldahl, where the cost estimates for JT Myers were used as a basis for Newburgh and the authorized cost estimate for Greenup was used as a basis for Meldahl. In each case, the intermediate cost was selected as the best estimate for this stage of study. The cost to extend the auxiliary chamber at Newburgh was $140 million, and Meldahl extension cost was $162 million. The appropriate cost was applied to each extension of the 600' auxiliaries along the Ohio River.

9.3.7 Refinements To Accommodate Environmental Concerns

1. Detailed, project specific recommendations cannot be effectively presented in a programmatic document. Appropriate environmental studies and recommendations for ecosystem protection and mitigation would be conducted during, and in close coordination with, the process of project feasibility study and design. This maximizes the opportunity to produce projects in which desired environmental outcomes are designed into the project. Specific examples of such an approach include design of aeration function at dam gates to ensure optimal oxygen levels in downstream reaches and design features to optimize aquatic habitats in the vicinity of the project, and designs to facilitate fish passage through locks and dams.

2. The opportunity to realize desired environmental outcomes at the project specific level will be enhanced by the presence of proactive programs designed to monitor ecosystem conditions and identify restoration needs on a regional or watershed scale. This perspective helps to determine conditions that are achievable and improves opportunities to identify key restoration measures that might be overlooked at the project specific level. Although some elements are in place, a comprehensive approach for the Ohio River has not yet been realized.

3. Several ecosystem restoration measures have been identified that could address both project specific and more systemic issues on the Ohio River. These measures were addressed in Sections 8.5 and 8.8 of the preceding chapter as well as in Sections 9.4, 9.7 and 9.8 of this chapter. Further analysis and recommendations are presented in Section 10.2 and 10.3.

9.4 SUSTAINABILITY MEASURES (NOT RELATED TO LOCK CONSTRUCTION) CONSIDERED

9.4.1 Existing Authorities

All existing authorities, implementation of Reasonable and Prudent Measures, and the corresponding array of measures considered in the WOPC to address ecosystem sustainability are carried forward for WPC evaluations. See Section 8.5 and **Tables 8-6 and 8-7**.

9.4.2 Seeking Additional Authorities

1. While there are numerous existing federal authorities available to begin addressing ecosystem sustainability needs, some of the necessary actions can only be taken with additional new authority. Also, there are some needed actions for which it is not clear whether authority currently is adequate or if new authority is needed. For example, modification of existing dams to enhance fish passage might be considered under Section 1135, Section 216, the Ohio River ERP, or possibly navigation project authorities. However, depending on the nature and cost of providing such facilities,

implementation could involve their inclusion in a mitigation plan as a component of a site-specific feasibility study recommending a new navigation authorization or as a separate project independent of any navigation improvements.

2. **Table 9-10** provides an assessment of major ecosystem sustainability enhancement opportunities and possible authorities for implementation. These opportunities were identified in consultation with Ohio River resource experts and are carried forward from Tables 6-5 and 8-6. One action (dismantle federal tributary dams) was identified that clearly could not be performed through existing authority. Considering authorities and programs of the Corps of Engineers, along with those of other governmental agencies and non-governmental organizations, there are numerous potential avenues to improve long-term ecosystem sustainability. Some common problems related to use of the authorities and programs include 1) lack of consensus on high priority needs, 2) real or perceived obstacles to collaborative efforts, and 3) inadequate funding. In other words, the Ohio River currently lacks a multi-agency comprehensive plan (i.e., a unity of vision) that would assure environmental sustainability and the dedicated financial resources to execute such a plan.

3. To address the problem of consensus on high priority needs, the ORMSS process brought together groups of specialists familiar with conditions of Ohio River resources to begin developing consensus on high priority needs. Through establishment of the Interagency Working Group, the study process substantially reduced obstacles to collaborative efforts by developing working relationships and trust among a variety of interests. However, it is essential that these parties continue to work together on common interests to further the relationship building process and to pursue elimination of obstacles. The lack of adequate funding remains a very large impediment to making real progress toward more sustainable ecosystems.

4. For the near term, it may be more fruitful for the collaborating interests to jointly pursue additional funding under existing authorities than to seek new authorities. There are many good examples in various regions of the US (e.g., Upper Mississippi River, Florida Everglades, fisheries restoration in the Pacific northwest) where growing recognition of needs and public support for solutions have resulted in significant funding for ecosystem restoration. Although authorities exist to address many opportunities, some of these could only be applied on a small scale, at certain locations, or within prescribed requirements. Over the long term, additional authority could be pursued to address opportunities at a greater scale, in additional areas, or with fewer restrictions. The actual measures would include seeking the necessary authorization where necessary.

TABLE 9-10
Major Ecosystem Sustainability Enhancement Opportunities

Opportunities for Enhancing Ecosystem Sustainability	Without Project	Potential Authorities for Implementation[1]					
		Mitigation related to Specific Navigation Project Authorization	Specific Authorization	Congressional Deauthorization	Specific Congressional Authorization for Ecosystem Projects	Comprehensive Watershed Management Planning	Modified Ohio River Ecosystem Restoration Program[2]
Enhance fish passage around or through dams	x	o					
Dismantle federal tributary dams				o			
Dismantle non-federal tributary dams	x				o		
Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats	x	o			o		o
Allow more natural flows to mimic natural regimes including seasonal and extreme floods and droughts	x	o			o		o
Restore unique mainstem habitats such as canebrakes, river bluffs and mussel beds	x						
Protect tailwaters and provide structures to serve as refugia for fish	x	o					
Create spawning shoals and other in-stream features to enhance habitat diversity in pools	x	o				o	o
Identify and expand areas of submerged and emergent aquatic vegetation	x					o	o
Protect and manage mussel populations and their habitat on a site-specific basis	x						o

TABLE 9-10
Major Ecosystem Sustainability Enhancement Opportunities

Opportunities for Enhancing Ecosystem Sustainability	Without Project	Potential Authorities for Implementation[1]					
		Mitigation related to Specific Navigation Project Authorization	Specific Authorization	Congressional Deauthorization	Specific Congressional Authorization for Ecosystem Projects	Comprehensive Watershed Management Planning	Modified Ohio River Ecosystem Restoration Program[2]
Mark critical locations to prevent mooring near mussel beds or special shoreline areas	x						
Mark shallow mussel beds to reduce direct impacts of tow traffic	x						
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources	x						
Protect existing aquatic habitats, restore lost habitats and diminished resources	x	o			o		
Reintroduce native fauna and expand the range and populations of native fauna from reduced levels	x	o			o		o
Control exotics, including minimization of existing populations and prevention of new introductions	x	o			o		o
Reduce bacterial contamination from combined sewer overflows	x		o				
Address point and non-point sources affecting aquatic nutrient balance	x					o	o
Minimize catastrophic contamination events through reduction of spills, accidents, and	x						

TABLE 9-10
Major Ecosystem Sustainability Enhancement Opportunities

Opportunities for Enhancing Ecosystem Sustainability	Without Project	Potential Authorities for Implementation[1]					
		Mitigation related to Specific Navigation Project Authorization	Specific Authorization	Congressional Deauthorization	Specific Congressional Authorization for Ecosystem Projects	Comprehensive Watershed Management Planning	Modified Ohio River Ecosystem Restoration Program[2]
improvement of spill response procedures							
Continue remediation of CERCLA, brownfields, and other contaminated sites	x		o				
Reconnect and restore floodplains on the mainstem and tributaries	x				o		o
Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries	x	o			o		o
Maintain or restore tributary deltas and connections between rivers and embayments	x	o			o		o
Reforest lower reaches of tributaries to reduce siltation into embayments and mainstem	x					o	o
Restore wetlands in upper ends of tributary embayments to reduce siltation and create fish and wildlife habitat	x					o	o
Conduct economic evaluation of watershed functions and benefits	x					o	

[1] Authorization may exist to address an opportunity at a smaller scale, at certain locations, or with prescribed requirements. Additional authority could be required to address opportunity at a greater scale, in additional areas, or with fewer restrictions

[2] Modifications to the existing Ecosystem Restoration Program may include changes in geographic scope and/or definition of project sponsor. NOTE: The Ohio River Ecosystem Restoration Program has yet to receive Congressional appropriations for implementation and is now a candidate for de-authorization.

9.5 REAL ESTATE CONSIDERATIONS

1. As previously stated, the primary purpose of the SIP is to serve as a guidance document for implementing new management practices, initiating non-structural efficiencies, and establishing budgets for future major rehabilitation and/or feasibility studies. To do this, the SIP will identify where, and approximately when, various improvements should be made along the Ohio River during the time period 2010-2070. **The SIP will not recommend any specific projects for Congressional authorization**; such authorizations would result from future Feasibility studies that focus on site-specific improvements. Because of the nature of this report a Real Estate Plan (REP) as described in ER 405-1-12 Chapter 12 is not included. Any future feasibility reports seeking authority to implement specific projects would contain complete detail in the form of a REP. Additionally, supplemental Real Estate Design Memorandums (REDMs) may need to be prepared in accordance with applicable Corps (ER 405-1-12) and HQ/Division guidance.

2. In all cases in this report, any inclusion of or reference to, real estate costs are based on preliminary venture level cost estimates and/or historical data. All references to real estate issues and cost in this report are tentative in nature and subject to change. Again, any future reports seeking project authorization would contain full documentation of real estate issues including a REP and Baseline Cost Estimate for Real Estate (BCERE).

9.6 SYSTEM INVESTMENT PLAN ALTERNATIVES

9.6.1 Proactive Maintenance Alternatives

Two proactive maintenance alternatives are built up from the reactive maintenance (WOPC) alternative as described below. As with the baseline alternative, routine and cyclical maintenance practices are continued and major components are repaired after failure.

9.6.1.1 Advanced Maintenance Alternative

Under the Advanced Maintenance Alternative (AMA), where economically justified, components are replaced before failure. No more than one component is replaced in any given year (components are not bundled together to share mobilization/de-mobilization costs and/or closures).

9.6.1.2 Major Rehabilitation Alternative

Under the Major Rehabilitation Alternative (MRA), major rehabilitations usually involving replacement of "bundles" of components are allowed where economically justified. This alternative also includes all operations and maintenance measures included in the Advanced Maintenance Alternative.

9.6.2 Lock Modernization Alternative

The Lock Modernization Alternative (LMA) includes all operations and maintenance activities allowed in the Major Rehabilitation Alternative as well as all lock modernization measures carried forward.

9.6.3 Summary of With-Project Condition Alternatives

Table 9-11 summarizes the alternatives and measures involved in each WPC alternative and includes the Reactive Maintenance Alternative (WOPC) for comparison. All appropriate measures are considered for all traffic forecast scenarios.

9.7 DIRECT, INDIRECT, AND CUMULATIVE EFFECTS OF NAVIGATION INVESTMENT ALTERNATIVES

Potential direct and indirect effects on major VECs of the three alternatives (AMA, MRA and LMA) considered under With-Project Conditions are presented in **Table 9-12**. Each of the WPC alternatives is briefly described. The major portion of **Table 9-12** is associated with "cells" containing descriptive information on the effects (impacts) of the 3 WPC alternatives on the six major VECs; namely, water quality, fish, mussels, riparian resources, recreation, and health and safety. These six VECs were designated as major based on inputs from the Interagency Working Group and various publics, recognition of their inherent importance in the environment of the Ohio River Mainstem, and their susceptibility to damage from multiple governmental and private actions in the Mainstem environs. **Table 9-12** also includes codes in the upper parts of cells to denote whether the anticipated effects are detrimental or undesirable (denoted by a "-" sign), beneficial or desirable (denoted by a "+" sign), or a mixture (denoted by a "-/+" sign). This table follows the format utilized for WOPC in **Table 8-9**.

TABLE 9-11

Navigation Measures in Each Investment Alternative

Alternative Includes Measures:	*Reactive Maintenance Alternative (RMA)*	*Advanced Maintenance Alternative (AMA)*	*Major Rehabilitation Alternative (MRA)*	*Lock Modernization Alternative (LMA)*
Routine Maintenance	X	X	X	X
Cyclic Maintenance	X	X	X	X
Unscheduled Component Replacement	X	X	X	X
Scheduled Component Replacement	X		X	X
Major Rehabilitation			X	X
N-up/N-down Lockage	X	X	X	X
Industry Self-Help	X	X	X	X
Adjustments by Industry During Main Chamber Closures	X	X	X	X
Mooring Cells (existing)	X	X	X	X
Tow Haulage (existing)	X	X	X	X
Coordination with Industry	X	X	X	X
Lock Extensions*				X
New Locks**				X

*600' Lock Extensions of 110'x600' auxiliaries (resulting in 110'x1200' chamber) considered at Meldahl, Markland, Cannelton and Newburgh.

**New 110'x600' or 110'x1200' locks to replace 56'x360' auxiliary chambers at Emsworth, Dashields and Montgomery.

TABLE 9-12

POTENTIAL DIRECT AND INDIRECT EFFECTS ON MAJOR OHIO RIVER VECS IN WITH PROJECT CONDITIONS*

WPC Alternatives	Description of Alternatives	Impacts on Major VECS					
		Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**	Health & Safety
With Project Conditions not only include the three alternatives described in this table, but also all maintenance, operational and low-cost structural measures for Without Project Reactive Maintenance Conditions, as listed in Tables 8-4 and 8-5__.							
Advanced Maintenance Alternative (AMA)	Includes replacement of specific L & D components as they age, when economically feasible. More proactive than Reactive Maintenance and should reduce number of unscheduled repairs. Miter gate replacement is the most complicated and costly item under this alternative.	-/+ Impacts to major VECs would be similar to those listed in Table 8.9 for Cyclical Maintenance except impacts would be reduced in proportion to the benefits associated with more proactive maintenance and the resulting reduction in unscheduled repairs. Advanced notification to shipping industry would lead to some reduction in queuing and its associated impacts					
Major Rehabilitation Alternative (MRA)	Involves major component or repair work that exceeds a specified monetary threshold adjusted annually. Where feasible, components may be "bundled" for budgetary and temporal economies of scale. . Long-term, MRA should	-/+ Impacts to water quality, as well as to fish, mussels and riparian resources would be similar to those occurring during AMA. The potentially longer duration of activities under MRA may exacerbate some impacts, but this would be compensated by a reduction in total number of repair activities. As with AMA, operational actions to notify shippers and reduce river traffic would reduce these negative impacts. As with the AMA, seasonal timing is important. For example, an 18-month rehab, may be planned such that only one fish spawning season (or one recreational season) is affected instead of two. MRA involves longer durations and more complicated projects than AMA or reactive maintenance. On the positive side, however, bundling of replacement components would					-/+ Impacts would be similar to AMA. However, the risk of accidents may be increased because major rehabs are often longer in duration and involve more workers and types

	result in fewer repair events and less time under closure conditions than AMA or reactive maintenance.	realize both time and cost efficiencies by reducing the number of projects and the need for future repair closures. Unlike emergency repairs, MRA is planned well in advance and, consequently, could include opportunities to avoid, minimize or mitigate adverse direct or indirect impacts.		of equipment.
Lock Modernization Alternative (LMA)	Involves possible new 110' x 600' and 110 x 1200' locks at Emsworth, Dashields and Montgomery (EDM) and possible auxiliary lock extensions at 14 L & Ds (Meldahl, Markland, Cannelton, and Newburg). Congestion conditions are currently most serious at EDM.	-/+ Short term impacts to water quality would be similar to those for AMA and MRA, but of greater duration. Additionally, this alterative involves major dredging and excavation in the river which may result in long-term changes in sediment transport and flow patterns that may erode river banks and nearby islands. Dredging and excavation during construction would destroy aquatic habitat in the impact area and could cause turbidity and siltation of adjacent habitats that may interfere with feeding and reproduction of aquatic life. Clearing of riparian areas during construction would remove habitat and affect local hydrology. Such areas may require decades to return to pre-disturbance conditions. Prop wash and scour is known to cause some larval fish mortality. Positive aspects of LMA include long-term reduction in tow queuing and its adverse effects on aquatic habitat, as well as providing opportunities to add project design measures (e.g. facilitation of fish passage) to enhance environmental sustainability. -	-/+ Short-term negative impacts associated with construction. Access through dam likely to be restricted to commercial vessels. Long-term impacts would likely be positive as new, extended, or replaced locks would be more efficient & dependable, providing greater capacity to handle recreational boaters. Related long-term negative impacts to fisheries may result from cumulative	-/+ New locks or extensions would provide increased capacity for commercial and recreational vessels that would relieve congestion associated with queuing, particularly when main lock chambers are closed during maintenance. This would facilitate safer, more efficient movement of traffic. Strict enforcement of onsite safety regulations for workers and the public and proper disposal of all construction materials, effluents and other wastes would minimize risks.

			impacts of increased commercial & recreational navigation.	Vessel congestion and conflicts during construction could be alleviated through structural and operational measures.

9.7.1 Impacts to Valued Environmental Components

To parallel the analyses in Section 8 (WOPC), a careful review of the information in **Table 9-10 and Table 9-12** was made. Based upon that review, the following general observations can be made:

- Regarding the Advanced Maintenance Alternative (AMA), the associated component replacements would cause localized and limited effects on the six VECs. Some maintenance actions related to major lock component replacement would be expected to require lock chamber dewatering. Dewatering can cause short-term detrimental effects relative to increased water turbidity, interference with upstream movement of fish, damage to fish habitat in tailwater areas, disruptions in downstream mussel habitat, damage to riparian resources due to the queuing of tows and their bank toe-ins and tie-offs, and disruption of recreational boat lockages. The impacts of a specific replacement action would be related to its duration and the time of year it is performed. For example, if fish spawning was known to occur in an impact area, an action's effects would be expected to be more pronounced if component replacement occurred during the spawning season rather than during other times of year. On the positive side, because AMA is more proactive than Reactive Maintenance, as described in the WOPC, it would result in a long-term reduction in the number of unscheduled repairs and the more detrimental and unpredictable environmental effects associated with them.

- Regarding the Major Rehabilitation Alternative (MRA), the associated actions would have impacts similar to those occurring under the AMA. To attain budgetary and temporal economies of scale, however, several components requiring replacement may be grouped or "bundled" into one large rehabilitation project, thus avoiding smaller repeated repair events. For example, an 18-month rehabilitation project may result in a 40-day closure in contrast to three 9-month events under AMA involving 20-day closures for each event. Although proactive like AMA, the MRA involves more complex actions that are of greater duration; accordingly, some impacts may be exacerbated during MRA. As with AMA or any scheduled repair or replacement, timing is important. It may be possible, for example, to time an 18-month major rehabilitation so it would interfere with only one recreation season instead of two.

- Regarding the Lock Modernization Alternative (LMA), the associated actions would be more complex than the AMA, MRA or actions planned under the WOPC. Although similar in many ways to the AMA and MRA, the LMA would have more pronounced environmental impacts of longer duration than under either AMA or MRA. Further, unlike all previous maintenance alternatives, which involve various degrees of repair & upkeep of existing facilities, LMA constitutes new, in-stream construction. Impacts always associated with LMA include:
  - Permanent loss of aquatic habitat within the 'footprint' of the new construction (about 2 acres for a new 600'x110' lock at EDM)

- Permanent modification of flow patterns downstream of LM area
- Temporary instream construction impacts such as blasting/dredging/removal of substrate and turbidity and sedimentation

Other impacts that may occur with LMA include:
- Permanent loss of aquatic habitat if new approach dredging is required
- Permanent loss of riparian habitat if construction or approach pattern requires bank reconfiguration

Dredging and excavation in the river are particularly important actions during lock modernization and would have localized impacts that would be considerably more extensive both in area affected and in duration than in either the AMA or MRA option.

- In comparing and contrasting impacts of With Project and Without Project Conditions, one must continue to bear in mind that all operational and low-cost structural actions discussed in Section 8 that reduce queuing are applicable to both cases, as appropriate. Most operational and low-cost structural actions have beneficial effects, including reductions in localized water turbidity levels; decreases in disruptions to habitats for fish, mussels, and riparian resources; and lowered accident potentials. Both permanent and temporary mooring cells are expected to cause negative and positive effects on the six VECs. Depending upon their location, negative effects could occur from mooring cells that are located over or near mussel beds, disrupt fish habitat, or are near erodible shorelines. Positive effects related to appropriately sited mooring cells could result from reductions in queuing and the minimization of dispersed damages to habitats.

From the perspective of the potentially impacted VECs, the following can be noted from **Table 9-12**:

- The AMA and MRA have similar short-term, localized effects on the Water and Sediment Quality VEC related to increased turbidity, changes in oxygen levels and release of contaminants from disturbed sediments. Impacts, resulting from lock closures, queuing, and construction activities would be partially attenuated by the 4 operational actions and the 3 low-cost structural actions described in **Table 8-9,** all of which apply to the WPC. The LMA, in contrast, involves more extensive dredging and in-river excavation which would exacerbate water quality and sediment impacts both in extent of area affected and duration. Additionally, alterations in long-term sediment transport may occur in a localized area as a result of new locks. With the water and sediment quality VEC, as well as with the remaining VECs, impacts become increasingly pronounced progressing from AMA to MRA and, finally, LMA. On the positive side, beneficial effects would accrue over the long term by minimizing localized turbidity levels from tow queuing, particularly in tailwater areas below the locks.

- The AMA and MRA have similar short-term, localized effects on the Fish VEC, including sediment resuspension and deposition, disruption of seasonal feeding or spawning patterns, and disruption of fry and larval life stages. Dredging and excavation during the LMA, however, would increase the severity of these impacts with permanent loss of aquatic habitat occurring within the 2+ acre project footprint. Further, placement of fill materials around the foundations of extended lock walls could cause siltation of fish habitat or may permanently eliminate it. Because of its long-term planning horizon, the LMA also may offer opportunities to enhance fish passage through construction of new structures or adaptations of older ones.

- As with the Fish VEC, the AMA and MRA have similar short-term, localized effects on the Mussel VEC, including turbidity, scouring and sediment deposition, that could disrupt feeding and reproduction. The duration of impacts such as sediment deposition and flow alterations could continue beyond the actual periods of disturbance. The effectiveness of operational and low-cost structural practices designed to minimize impacts would be enhanced by carefully documenting the location of mussel populations in proximity to the project and potential queuing areas prior to initiation of such disturbances. In the LMA, placement of fill materials around the foundations of extended lock walls could cause siltation of mussel beds or permanently eliminate them.

- Impacts to the Riparian Resources VEC are localized and are similar for the AMA and MRA options, although the duration of such effects is expected to be longer in the MRA. Among the impacts are potential damage to riparian resources from queuing and toe-ins and tie offs, but operational and low-cost structural measures in place under both WPC and WOPC help to minimize these impacts. Fewer repair events resulting from AMA or MRA, in contrast to reactive maintenance of the WOPC, would be beneficial in sustaining riparian resources. The long-term, extensive nature of LMA, however, could have more lasting impacts on riparian resources. Clearing activities and subsequent changes to local hydrology may take decades to return to previous patterns. Further, temporary or long-term alterations in river flow may cause erosion of riverbanks or nearby islands.

- Impacts to the Recreation VEC under the AMA option would likely be similar to those for Reactive Maintenance. The MRA option may be more restrictive and limit or prohibit passage of recreational vessels through the locks during construction. Wherever recreational lockages are permitted in the WPC, operational and low-cost structural measures will facilitate passage of commercial vessels, in turn, making it more efficient for recreational vessels to pass through. In the LMA option, however, passage of recreational vessels may be prohibited for extended periods repeated over the multi-year construction of the project. These inconveniences may be compensated somewhat by the availability of recreational opportunities elsewhere on the river. Long-term impacts to recreation would be positive, however, as LMA is predicted to increase lock capacity and efficiency.

- Impacts to the Health and Safety VEC under the AMA and MRA would be similar to those under the Reactive Maintenance alternative of the WOPC, although the duration of risk will be longer, especially under the MRA. Concerns will be minimized if workers and others adhere to the Corps' proactive safety procedures. Closure of lock and dam areas to visitors and temporary suspension of recreational lockages are examples of such proactive measures. The operational and low-cost structural measures applicable to the WPC and WOPC also contribute to safety by reducing congestion in the vicinity of construction activity. In contrast to AMA and MRA, the LMA option involves a longer time period of more intensive activity and, therefore, greater risk of accident and injury. Again, strict adherence to proactive safety measures would minimize concerns. In the long-term, alleviating congestion by providing more efficient vessel passage through modernized locks would have beneficial safety effects for both commercial and recreational vessels.

9.7.2 Cumulative Effects

The final consideration related to the direct and indirect effects of the WPC alternative, comprising the Advanced Maintenance Alternative (AMA), Major Rehabilitation Alternative (MRA), and Lock Modernization Alternative (LMA), focuses on two issues – the anticipated relative contributions of the three WPC alternatives to current and future cumulative effects on the six VECs, and the influence of the three WPC alternatives on the current and future environmental sustainability (ES) of the six VECs. These two issues are addressed as follows:

- Under current conditions, negative water quality effects of the AMA and MRA are expected to be similar to Reactive Maintenance; that is localized, short-term, and relatively minor. Bundling of components under the MRA would likely result in fewer repair events than under the AMA, although a major rehabilitation would generally be of longer duration than an AMA event. Continuing through the 60-year planning horizon for ORMSS, the number of lock closures and repair activities associated with AMA and MRA would be expected to decline relative to the proposed aggressiveness and consistency of maintenance as lock components age, as well as to traffic levels at each lock. The rate at which such traffic levels change is illustrated in the 5 traffic scenarios.

- A major cumulative benefit to the water quality, fish, mussels and recreation VECs under the LMA would be the long-term reductions in queuing. Completion of new 600' locks at EDM and improved reliability elsewhere on the river would be expected to significantly reduce queuing by reducing the number of future repair events at these projects.

- In contrast to AMA and MRA, LMA would more profoundly and permanently affect aquatic and riparian resources and result in a net loss of

aquatic habitat and riparian vegetation. Site-specific impacts at LMA sites would be directly related to the pre-construction quality and quantity of these resources. Because of the precariousness of the mussel resource in the Ohio River mainstem and mussels' limited mobility, any loss or damage to large mussel beds near locks would contribute to an overall decline in their Environmental Sustainability (ES). LMA projects may result in permanent modification of flow patterns downstream which may affect sediment transport and necessitate additional maintenance dredging. Riparian resources would be expected to be more resilient, but their ES also would be lowered over the decades required to recover to pre-construction conditions.

- Scheduled, proactive maintenance of locks and dams under AMA and MRA would sustain recreational activities on the river. The effects of closures during L & D maintenance and repair would not only be related to the length of associated closures, but also to the time of year of closures and the boating population of a specific pool. Similar cumulative effects would occur with LMA, but with more enhanced long-term benefits to recreation in terms of lock reliability and capacity. Under all WPC alternatives, advanced notice of lock closures and the availability of alternative launch sites and other recreational facilities would reduce temporary inconveniences to boaters and fisherman.

- Health and safety risk factors would rise in direct proportion to the cumulative increase in the number and duration of repair activities. Because work activities under WPC are planned in advance, however, there should be sufficient time to plan and implement applicable Corps procedures to minimize health and safety concerns.

9.8 FORMULATION OF ECOSYSTEM RESTORATION WITH-PROJECT ALTERNATIVES

9.8.1 Methodology

1. In Section 8.5, **Tables 8-6 and 8-7** identify a spectrum of program authorities by which the Corps, other state or federal agencies, or private organizations, may be able to initiate efforts to improve the environmental sustainability of certain Ohio River resources. **Table 8-6** compares a list of 26 opportunities for enhancing ES with existing authorizations and related programs or responsibilities of the Corps. A category is also included for other agencies and NGOs, which was expanded upon in this Section (see **Table 9-10)** and which addresses ES authorities of other governmental agencies.

2. **Table 8-10** also listed the opportunities for ES enhancement and their potential effects on the major VECs, excluding Health & Safety. These opportunities were organized into 4 groups that reflect progressive levels of implementation complexity. **Table 8-10** is not repeated here because the listed ES measures are not strictly dependent

on Without- or With-Project Conditions, although implementation of some opportunities may be more likely under a WPC that provides authorization and funding.

3. To reiterate information presented with **Table 8-10**, the 26 ES measures are organized as follows:

- Group A: Measures for which authority already exists and which involve minimal costs. These measures would also increase awareness of key VECs, focus on impact prevention, and could be implemented relatively quickly.

- Group B: Measures for which authority already exists, but which would require some costs for planning and/or construction. These measures focus on key VECs and incorporate restoration and enhancement.

- Group C: Measures for which some authority already exists, but new authority may be needed for some opportunities. Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement and the focus tends toward broader-level environmental needs.

- Group D: Measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement, and the focus tends toward broader-level environmental needs.

4. These measures and their groupings are reconsidered in Section 9.8.2 with regard to the WPC.

9.8.2 Sustainability in the With-Project Condition

1. All authorities and operational measures for implementation of ES opportunities applicable to the WOPC also apply to the WPC. Consequently, the 14 ES measures listed in Groups A and B in Table 8.10 can be implemented under existing authority in both the WOPC and WPC. While some opportunities among the 14 are relatively low-cost and straightforward, others would require additional planning and/or construction.

2. The implementation of the costlier and more broadly focused ES opportunities in Group C would require new authorization and additional funding to become more feasible under the WPC than under the WOPC. For example, potential changes in flow regimes to induce seasonal flooding may be considered in the context of engineering activities included in the WPC. Other activities in Group C, including reconnecting and restoring streams and floodplains may be feasible near locks and dams undergoing major rehabilitation or extension. In areas not closely associated with locks and dams, the likelihood of reconnecting and restoring streams and floodplains would be greatly

enhanced if Congress were to allocate significant funding for implementation of the Ohio River Ecosystem Restoration Program (ERP) or some other means.

3. In some cases, Group D activities, such as reducing bacterial contamination from combined sewer overflows, are clearly beyond the authority of the Corps, but may be encouraged through collaboration with other federal agencies in an overall restoration and adaptive management program for the Ohio mainstem. Other activities – enhancing fish passage around or through dams; dismantling of federal dams along Ohio River tributaries, and conducting economic evaluations of watershed functions and benefit – appear to be within the purview of the Corps. Such Group D activities are more likely to occur with WPC authorization and/or funding than in the WOPC. For example, fish passage enhancements could be designed and budgeted for in future rehabilitations or modernizations of Ohio River mainstem locks and dams, whereas dismantling Federral dams would require specific Congressional authority.

4. Table 8-10 represents a seemingly comprehensive list of ES opportunities, but continuing research in environmental sustainability, changing technologies, and potentially innovative funding sources will ensure the list of opportunities will grow over the long planning horizon of ORMSS.

5. These groups of measures are aggregated into two WPC ecosystem alternatives, Groups A, B and C comprises the "moderate" plan, and all four groups comprise the "maximum plan." These alternatives are evaluated and compared to the "minimum" plan (corresponding to the ES WOPC) in Section 10.

SECTION 10
EVALUATION OF ALTERNATIVE SYSTEM INVESTMENT PLANS

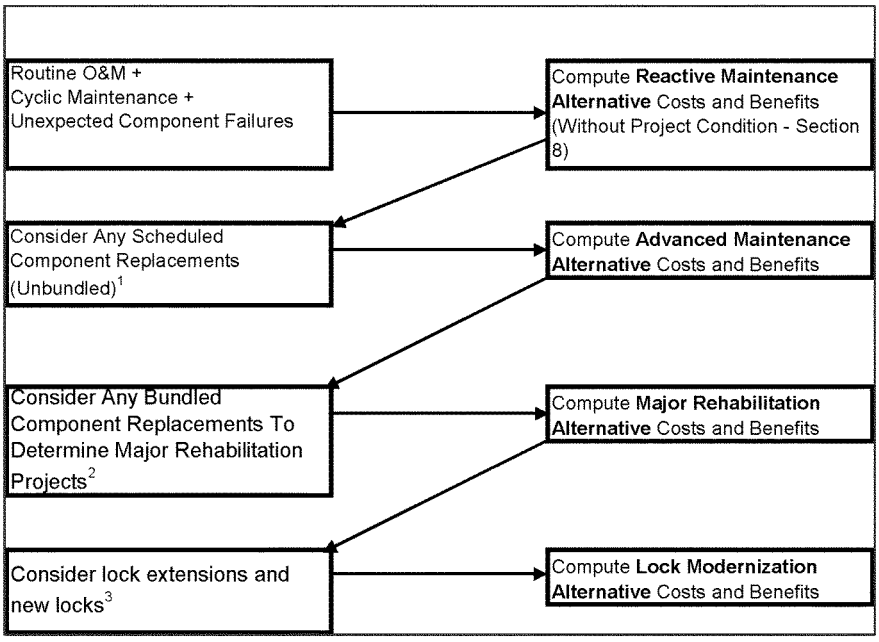
This section describes in detail the economic and environmental aspects for the System Investment Plan determined for each of the traffic scenarios. Economic methodology, results for each of the three With Project Condition (WPC) alternatives and selection of the WPC National Economic Development System Investment Plan are presented in Section 10.1. Environmental assessments of the WOPC and WPC Plan are presented in Section 10.2. Based on the evaluation criteria described in Section 10.3, a schedule of investments combining navigation and environmental sustainability measures is tentatively selected as the Combined National Economic Development/National Ecosystem Restoration Plan. This plan serves as a basis for initiating actions ranging from budget submittals to scheduling future site specific major rehabilitation and feasibility studies. This section completes the fourth, fifth, and sixth step of the plan formulation process (Sections 2.4.4, 2.4.5 and 2.4.6 respectively).

10.1 ECONOMIC SYSTEM ANALYSIS

10.1.1 Methodology

1. The general process (top-down) used to evaluate With-Project Condition alternatives is shown in **Figure 10-1**. The top step shows the evaluation of the Without-Project Condition that was described and evaluated in Section 8 and which forms the baseline from which all WPC alternatives are compared. The WPC alternatives described in Section 9 are evaluated in order of increasing latitude of maintenance or lock improvement options. The first WPC alternative is advanced maintenance that only allows for component replacements. The second is the major rehabilitation alternative that allows for bundling component replacements into larger projects meeting MR requirements, and finally the lock modernization alternative that incorporates all possible proactive maintenance strategies as well as construction of lock extensions or new locks. Costs and benefits are determined for each alternative and compared to the WOPC to determine economic justification.

Figure 10-1
Process To Evaluate Economics of WPC Alternatives



[1]For components for which a scheduled replacement is economically justified, this step would reduce or eliminate repair and navigation delay costs due to unexpected failures obtained in the first step. Costs are not necessarily eliminated unless the component replacement is performed at the beginning of the analysis period since a component could then fail prior to the date established for the replacement.

[2]For components included in a Major Rehabilitation project, his step could reduce repair and navigation delays costs obtained in the prior step for unscheduled or scheduled replacement.

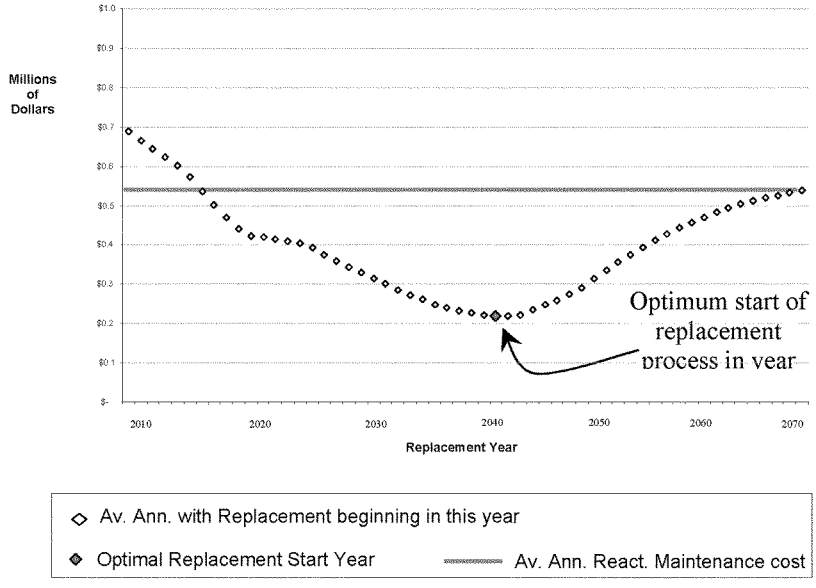
[3]This step could reduce maintenance costs and navigation delays through construction of new locks or lock extensions.

2. The timing of any scheduled component replacements are determined in step four in the following fashion. Through the use of ORNIM, the optimal year to schedule the replacement of a particular component is determined, the associated economic cost is calculated, and that cost is compared to the expected cost obtained in the Reactive Maintenance Alternative. An example is shown in **Figure 10-2.** The points plotted for each year represent the equivalent annual cost of the scheduled replacement, taking into account the potential for failure (and replacement under emergency conditions) prior to that time. For example, to determine the expected cost of a scheduled replacement in 2020, the expected costs

2020, the expected costs to repair this component if it fails before 2020[1] is accumulated, and the probability of survival of the component up to 2020 calculated, and the expected up-front replacement cost is calculated. The year associated with the least cost is the year assigned for the scheduled replacement. As denoted by the horizontal line in **Figure 10-2**, the amortized costs determined in the Reactive Maintenance Alternative are approximately $0.54 million. Scheduling a replacement of this component in any year before 2016 would result in a higher amortized cost than the Reactive Maintenance strategy and therefore such a decision would not be sensible. Between 2016 and 2070 the amortized cost is less than the cost for the reactive maintenance strategy. It is a minimum in 2040, at about $0.21 million. Therefore, the year 2040 would be the scheduled replacement date for this particular component.

FIGURE 10-2

Example Comparison
Reactive Maintenance vs. Scheduled Replacement For Any Component



3. Navigation projects are composed of many components. Determination of optimal replacement timing of each component in the Advanced Maintenance Alternative is a critical step, but it may not indicate the best maintenance alternative for the project.

[1] Replacement of a component due to failure would eliminate the need for the scheduled replacement. A minor repair (for example, repair of the "minor" or "bad" conditions denoted in Figure 8-1) would not impact the scheduled replacement date.

is a critical step, but it may not indicate the best maintenance alternative for the project. Combining individual component replacements in a major rehabilitation might offer additional savings when compared to replacing those components individually in mobilization and de-mobilization costs and result in fewer chamber closures. Also, a large enough bundling of component replacements might eliminate enough collective reactive maintenance costs to be economically justified despite the up-front replacement of the individual components not being justified. This type of condition analysis of individual components and bundled components is useful in formulating possible chamber rehabilitation or replacement needs. This can result in a least-cost maintenance strategy for the Ohio River which could consist of a combination of reactive maintenance, advanced maintenance (component replacement), and chamber rehabilitation alternatives.

4. Lock extensions and new locks are considered in the final step. Such work may obviate the need for component replacements or major rehabilitation activities if the lock construction replaced the respective components prior to any scheduled replacement.

10.1.2 Advanced Maintenance Alternative

1. The advanced maintenance strategy allows for a component to be replaced before it fails. A planned, up-front component replacement can minimize the adverse navigation impacts of an unscheduled, emergency repair. Before advanced maintenance can be fully formulated at a project, optimal individual component replacements must be determined. Optimal individual component replacement represents a piecemeal maintenance strategy which can be more efficient than reactive maintenance. It is considered a viable stand-alone alternative although there might be more efficient "bundles" of component replacements. The bundling of components can lead to a major rehabilitation strategy and this is discussed in Section 10.1.3.

2. For each of these components and/or component systems analyzed at each site with the reliability analysis described in Section 8.7.1.1, ORNIM is used to calculate the expected costs of maintenance and repair and the additional transportation costs associated with the delays from the maintenance and repair closures. The amortized reactive maintenance costs are compared to up-front component replacement scenarios to determine if replacement is economically justified and if so, the optimal timing for the upfront replacement.

3. The resulting economically justified work at each lock and dam and for each traffic scenario is shown below but the emphasis of all discussions of economic performance of those alternatives is on river-wide (or system) benefits and costs, as the merit of alternatives is based on comparing aggregate statistics with those for the WOPC **(Table 8-8)**. Additional details for all WPC alternatives analogous to Sections 8.7.1.2 and 8.7.1.3 is provided in the **Economics Appendix**.

10.1.2.1 Advanced Maintenance Strategy for Each Project

1. The advanced maintenance alternative effectively combines reactive maintenance with economically justified component replacement. Components for which there are no economically justified replacement dates are thereby replaced only after failure as in the Reactive Maintenance alternative. **Tables 10-1** through **10-5** show the year for beginning the recommended component replacement schedules and reactive maintenance (RM) strategies for each project and traffic forecast scenario. The gray shaded cells represent components not expected to fail at any point in the analysis period such that there would not be any need for scheduled maintenance. RM represents reactive maintenance which is the same thing as fixing the component after failing, and the number in a cell represents the year which optimizes the start of the up-front component replacement process.

TABLE 10-1
Advanced Maintenance Alternative
Scheduled Component Replacement
Forecast Scenario – Clear Skies

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	RM	29	39	24	-	10	16	-	55	53	32	30	12	17	-	-	-	-
Gate Machinery	RM	18	RM	15	RM	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	16	15	15	30	36	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	38	10	10	RM	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	15	15	15	RM	15	27	-	24	10	10	10	RM	15	RM	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	RM	RM	RM
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	13	12
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	11
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	55	-	-	-	-	RM	10	-	-	-	-	-	RM	RM	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	58	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 10-2
Advanced Maintenance Alternative
Scheduled Component Replacement
Forecast Scenario – Modified Clear Skies

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	27	37	24	-	10	12	-	53	38	28	29	10	14	-	-	-	-
Gate Machinery	RM	10	15	22	RM	28	20	-	RM	RM	20	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	10	15	15	30	10	RM	-	RM	RM	20	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	22	37	10	10	RM	-	-	50	-	RM	RM	-	-	-	-	-
Electrical	RM	10	15	15	RM	10	10	-	10	20	10	23	RM	15	15	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	17	RM	38
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	51	-	-	-	-	RM	10	-	-	-	-	-	65	52	34	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	53	35	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 10-3
Advanced Maintenance Alternative
Scheduled Component Replacement
Forecast Scenario – NAAQS Growth

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	27	37	24	-	10	12	-	52	39	28	29	10	14	-	-	-	-
Gate Machinery	RM	10	15	15	RM	24	22	-	RM	10	10	RM	RM	15	RM	15	RM	RM
Hydraulic	RM	10	15	15	30	20	RM	-	RM	RM	RM	RM	RM	RM	RM	15	RM	RM
Culvert Valve	10	10	22	36	10	10	RM	-	-	54	-	RM	RM	-	-	-	-	-
Electrical	RM	10	15	15	RM	10	10	-	24	10	10	23	RM	14	15	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	15	35	16
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	10	14
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	50	-	-	-	-	RM	10	-	-	-	-	-	RM	52	34	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	53	34	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 10-4
Advanced Maintenance Alternative
Scheduled Component Replacement
Forecast Scenario – Utility Based

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	28	37	24	-	10	10	-	48	52	31	29	12	18	-	-	-	-
Gate Machinery	RM	15	27	20	RM	15	15	-	RM	15	RM	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	15	21	17	30	15	15	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	36	10	10	RM	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	10	17	15	RM	10	14	-	19	15	15	15	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	51	RM	RM
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	51	-	-	-	-	RM	12	-	-	-	-	-	RM	57	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	45	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	58	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 10-5
Advanced Maintenance Alternative
Scheduled Component Replacement
Forecast Scenario – Utility Based High

Ohio River Mainstem Project																			
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	51	27	37	24	-	10	10	-	45	52	30	29	12	16	-	-	-	-
Gate Machinery	RM	10	25	19	RM	15	14	-	RM	15	18	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	10	19	16	28	15	14	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	35	10	10	56	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	10	16	15	RM	10	10	-	14	15	15	15	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	33	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	35	RM	50
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	50	-	-	-	-	RM	10	-	-	-	-	-	RM	56	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	41	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	58	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	56	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

10.1.2.2 Summary of Advanced Maintenance Alternative Economic Statistics

1. **Table 10-6** summarizes average annual system benefits and costs from an advanced maintenance strategy at each mainstem project over the five traffic forecast scenarios analogous to **Table 8.8** for the WOPC (reactive maintenance). The actual dates of component replacement evaluated for each traffic scenario reflect the rule that not more than one component be replaced in any given year and therefore may vary slightly from the years shown in tables **10-1 through 10-5**. Scheduled improvement costs include component replacements and the remaining costs to complete the authorized Greenup and Myers projects. This level of proactive maintenance improves total system benefits from $95 to $124 million annually compared to the WOPC due almost solely to decreases in reduced or eroded savings (delays incurred at the locks). These decreases in eroded savings represent lower transit costs to the navigation industry. The total system benefits representing transportation cost savings range from $2.37 to $2.58 billion annually.

TABLE 10-6
Advanced Maintenance Alternative*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Advanced Maintenance Benefits					
Equilibrium Waterway Savings	$2,383.4	$2,543.2	$2,563.0	$2,590.8	$2,645.6
Reduced Savings from Unscheduled Repair	($17.6)	($74.4)	($37.0)	($56.3)	($61.2)
Total System Benefits	**$2,365.8**	**$2,468.8**	**$2,526.0**	**$2,534.5**	**$2,584.4**
Advanced Maintenance Costs					
Scheduled Lock Maintenance	$ 20.7	$ 20.9	$ 20.4	$ 21.1	$ 20.9
Scheduled Dam Maintenance	$ 6.9	$ 6.9	$ 6.9	$ 6.9	$ 6.9
Scheduled Lock Improvements**	$ 19.7	$ 15.0	$ 20.2	$ 15.2	$ 15.6
Unscheduled Lock Repair	$ 4.3	$ 8.4	$ 5.0	$ 7.6	$ 7.7
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$100.7**	**$100.4**	**$101.7**	**$100.0**	**$100.3**
Net Benefits	**$2,265.0**	**$2,368.4**	**$2,424.2**	**$2,434.5**	**$2,484.1**
BCR	**23.5**	**24.6**	**24.8**	**25.3**	**25.8**

**Note: Sums and differences may reflect rounding error.*

*** Scheduled Lock Improvements are 50% cost shared with the Trust Fund for the authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, plus any justified component replacements.*

2. The total system Federal plus Trust Fund costs for the AMA go up very slightly compared to reactive maintenance. Cost categories that differ from the WOPC costs in **Table 8.8** are shaded in gray in **Table 10-6**. Scheduled lock improvement costs increase ranging from $9.2 million to $14.4 million annually reflecting the justified component replacements. These increased costs are countered by reductions in scheduled lock maintenance and unscheduled lock repair costs across all forecast scenarios (less frequent cyclic maintenance and component failures), the former costs decease from $2.0 to $2.7 million, and the latter from $6.7 to $10.0 million annually. The total system costs for all alternatives is about $100-101 million annually for all forecast scenarios, representing very small increases of about $0.2 to $2.8 million annually over reactive maintenance. Taking all costs and benefits into account, the average annual net benefits to the nation range from $2.27 to $2.48 billion annually, generally a 2.5-3.0% increase over reactive maintenance.

3. **Table 10-7** displays incremental benefits and costs of advanced maintenance compared to reactive maintenance plans. There is a positive net benefit for all forecast scenarios indicating that in the long run, it is more economic to pursue an up-front component replacement strategy rather than a reactive maintenance strategy. The table shows incremental net benefits of a planned component replacement ranging from $94.8 to $172.4 million annually. These positive benefits indicate that the advance maintenance alternative is preferable to the WOPC (reactive maintenance) for all forecast scenarios

TABLE 10-7
Advanced Maintenance Alternative*
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$113.0	$95.1	$174.1	$105.8	$124.3
Incremental Costs over Reactive Maintenance	$2.8	$0.3	$1.7	$0.3	$0.2
Net Benefit	**$111.3**	**$94.8**	**$172.4**	**$105.5**	**$124.1**

*Differences subject to rounding error.

10.1.3 Major Rehabilitation Alternative

1. The major rehabilitation alternative (MRA) takes the advanced maintenance alternative one step further by allowing for major rehabilitation (MR) projects that effectively bundle individual component replacements into projects qualifying for the Corps MR program (described in Section 6.1.3). Since less mobilization and demobilization is required, rehabilitation costs and closures are usually improved over individual component replacements. If the bundled components did not exceed the rehabilitation threshold, then they were left as individual component replacements.

2. Recall that the only major rehabilitation option considered practical at Emsworth, Dashields, and Montgomery at this stage of study was reconstruction of the lock chambers and was screened out of the analysis at all three sites based on economic rationale.

10.1.3.1 Major Rehabilitation Strategy By Project

The MRA combines reactive maintenance with justified component replacements and chamber rehabilitations. **Table 10-8** summarizes recommended chamber rehabilitations for each traffic forecast scenario over the 2010-2070 timeframe. The gray shaded cells represent chambers where there was no group of components identified for a potential MR project due to a varied timing of individual component replacements. Cells with a "-" represent chambers where one or more bundles were identified as potential MR projects but were not determined to be economically justified. The year represents the start of the chamber rehabilitation process which is modeled with one year for a general investigation study and two years for the actual rehabilitation. The Greenup MR project is based on the authorized project and not due to any evaluations conducted through this study.

TABLE 10-8
Recommended Major Rehabilitations By Lock Chamber

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Olmsted					
Main					
Auxiliary					
Smithland					
Main	-	-	-	-	-
Auxiliary	-	-	-	-	-
Myers					
Main	2014	2011	2013	2013	2013
Auxiliary					
Newburgh					
Main	2025	2016	2016	2016	2016
Auxiliary					
Cannelton					
Main	2017	2017	2016	2017	2017
Auxiliary					
McAlpine					
Main					
Auxiliary					
Markland					
Main	-	-	2010	2010	2010
Auxiliary	-	-	-	-	2052
Meldahl					
Main	2013	2010	2010	2010	2010
Auxiliary	-	-	-	-	-
Greenup*					
Main					
Auxiliary					
R. C. Byrd					
Main	-	2044	2045	2030	2033
Auxiliary					
Racine					
Main	2020	2019	2020	2019	2019
Auxiliary					
Belleville					
Main	-	2017	2017	2017	2028
Auxiliary					
Willow Island					
Main	2027	2027	2027	2027	2028
Auxiliary					
Hannibal					
Main	2012	2011	2011	2012	2011
Auxiliary					
Pike Island					
Main	2016	2015	2015	2016	2015
Auxiliary	-	-	-	-	-
New Cumberland					
Main	-	-	-	-	-
Auxiliary	-	-	-	-	-

*The major rehabilitation of the Greenup main chamber recommended along with the lock extension project is assumed to begin in 2010.

10.1.3.2 Summary of Major Rehabilitation Alternative Economic Statistics

1. **Table 10-9** summarizes average annual system benefits and Federal plus Trust Fund costs for the MRA for each of the five traffic forecast scenarios. Scheduled improvement costs include MR projects according to **Table 10-8**, remaining costs to complete the authorized Greenup and Myers projects, and any remaining up-front component replacements is economically justified. Adding MR as a maintenance option has the effect of decreasing eroded savings (navigation delays due to unscheduled component repairs) by about $0.5 million to $2.0 million annually (compared to advanced maintenance). Compared to reactive maintenance, total system benefits are increased from $116 to $182 million annually, about the same incremental impact as for advanced maintenance. The total system benefits range from $2.37 to $2.60 billion annually.

TABLE 10-9
Major Rehabilitation Alternative*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Rehabilitation Maintenance Benefits					
Equilibrium Waterway Savings	$2,386.2	$2,565.1	$2,570.7	$2,602.1	$2,659.1
Reduced Savings from Unscheduled Repair	($17.6)	($62.7)	($36.9)	($56.1)	($61.5)
Total System Benefits	**$2,368.6**	**$2,502.4**	**$2,533.8**	**$2,546.1**	**$2,597.7**
Rehabilitation Maintenance Costs					
Scheduled Lock Maintenance	$18.3	$17.4	$17.0	$17.6	$17.5
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements**	$20.4	$16.7	$20.9	$16.7	$16.6
Unscheduled Lock Repair	$4.2	$7.4	$4.8	$7.3	$7.3
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$99.0**	**$97.6**	**$98.8**	**$97.7**	**$97.4**
Net Benefits	**$2,269.5**	**$2,404.8**	**$2,435.0**	**$2,448.4**	**$2,500.2**
BCR	**23.9**	**25.6**	**25.7**	**26.1**	**26.7**

**Sums and differences may reflect rounding error.*

*** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements plus justified rehabilitations.*

2. Costs and benefits that differ from the WOPC are shaded in gray in **Table 10-9**. Scheduled lock improvement costs for the MRA are increased over the corresponding WOPC expenditures by the cost of the MR projects and any remaining component

replacements, increases ranging from $10.8 to $14.6 million annually. These cost increases are counterbalanced by decreases in scheduled lock maintenance and unscheduled lock repair costs across all forecast scenarios, decreases ranging from $4.8 to $6.1 million annually for the former and from $7.4 to $10.2 million annually for the latter. The total system costs decrease from the WOPC in four of the forecasts, decreases ranging from $1.2 to $2.7 million and remaining the same in the fifth (Clear Skies). Taking all costs and benefits into account, the average annual benefits to the nation, representing total transportation savings to the navigation industry, range from $2.27 to $2.50 billion.

3. **Table 10-10** displays incremental benefits and costs of the major rehabilitation alternative compared to reactive maintenance. The table shows positive incremental net benefits of a planned component replacement ranging from $116 million to $183 million annually. These positive benefits indicate that the major rehabilitation alternative is preferable to the WOPC (reactive maintenance) for all forecast scenarios.

TABLE 10-10
Major Rehabilitation Alternative*
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$115.7	$128.7	$181.9	$117.4	$137.5
Incremental Costs over Reactive Maintenance	($0.0)	($2.5)	($1.3)	($2.1)	($2.6)
Net Benefit	**$115.7**	**$131.2**	**$183.2**	**$119.5**	**$140.2**

*Differences subject to rounding error.

10.1.4 Lock Modernization Alternative

The final alternative analyzed was the Lock Modernization, where 600' extensions of any 110'x600' auxiliary chamber and new 110'x600' and 110'x1200' locks to replace any of the small auxiliary chambers at EDM were considered. Lock extension plans were evaluated at Meldahl, Markland, Cannelton and Newburgh. In addition, the full complement of proactive maintenance measures were allowed as for the major rehabilitation alternative

10.1.4.1 Lock Modernization Strategy for Each Project

1. Lock extensions and new locks at EDM were systematically analyzed as described in the **Economics Appendix**. The first observation was that no auxiliary lock extensions were justified compared to major rehabilitation at any of the site. This suggests that a reliable main chamber negates the need for additional auxiliary capacity under the traffic forecast scenarios used in this analysis. Auxiliary lock extensions are

dropped from further analysis. However, replacements of the auxiliary lock chambers at EDM were justified up front in all five scenarios. The optimum sizes and timing for new locks are shown in **Table 10-11**.

2. For all other locks, the maintenance strategy is the same as for the Major Rehabilitation alternative.

TABLE 10-11
Economically Justified New 1200' or 600' Locks
At Emsworth, Dashields and Montgomery

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Emsworth					
Main	-	-	-	-	-
New 600' Lock	2010	2010	2010	2010	2010
Dashields					
Main	-	-	-	-	-
New 600' Lock	2011	2010	2010	2010	2010
Montgomery					
Main	-	-	-	-	-
New 600' Lock	2010	2010	-	2010	2010
New 1200' Lock	-	-	2010	-	-

10.1.4.2 Summary of Lock Modernization Alternative Economic Statistics

1. **Table 10-12** summarizes average annual system benefits and Federal plus Trust Fund costs of the lock modernization alternative for each of the five traffic scenarios. Scheduled improvement costs include new locks at EDM according to **Table 10-11**, remaining costs to complete the authorized Greenup and Myers projects, and any remaining up-front component replacements and major rehabilitation work that is economically justified. Adding lock modernization to the full complement of proactive maintenance measures in the major rehabilitation alternative significantly reduces eroded navigation savings over the major rehabilitation alternative by $5 to $38 million annually ($63 to $105 annually compared to reactive maintenance). Further, the full complement of proactive maintenance and new locks adds the greatest increment of total system benefits over the reactive maintenance, increases ranging from $148 to $260 million annually. The total average annual benefits range from $2.40 to $2.69 billion annually.

2. Scheduled lock improvement costs for this alternative are increased over the corresponding WOPC expenditures by the cost of the lock modernization projects and any remaining MR projects and component replacements, increases ranging from $37.2 to $41.8 million annually. These cost increases are counterbalanced by decreases in scheduled lock maintenance and unscheduled lock repair costs across all forecast

scenarios, decreases ranging from $7.9 to $9.2 million annually for the former and from $10.0 to $10.8 million annually for the latter. The total system maintenance and improvement costs increase from the WOPC, increases ranging from $18.4 to $21.5 million. Taking all costs and benefits into account, the average annual benefits to the nation, representing total transportation savings to the navigation industry, range from $2.28 to $2.57 billion annually.

TABLE 10-12

**Lock Modernization Alternative*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)**

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Optimum Lock Size at EDM Benefits					
Equilibrium Waterway Savings	$2,413.5	$2,631.5	$2,631.0	$2,656.5	$2,717.0
Reduced Savings from Unscheduled Repair	($12.9)	($20.7)	($19.4)	($20.8)	($23.6)
Total System Benefits	**$2,400.6**	**$2,610.7**	**$2,611.7**	**$2,635.7**	**$2,693.4**
Optimum Lock Size at EDM Costs					
Scheduled Lock Maintenance	$15.2	$14.0	$13.9	$14.0	$14.0
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements**	$43.0	$44.6	$47.6	$44.7	$44.5
Unscheduled Lock Repair	$4.0	$4.3	$4.2	$4.2	$4.2
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.2	$2.2	$2.2	$2.2	$2.2
Total System Costs	**$118.0**	**$118.7**	**$121.5**	**$118.7**	**$118.5**
Net Benefits	**$2,282.6**	**$2,492.0**	**$2,490.1**	**$2,517.0**	**$2,574.9**
BCR	**20.3**	**22.0**	**21.5**	**22.2**	**22.7**

**Sums and differences may reflect rounding error.*

*** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements, justified rehabilitations plus optimum construction of 1200'- 600' locks at EDM.*

3. **Table 10-13** displays incremental benefits and costs of the lock modernization alternative compared to reactive maintenance plans. The table shows positive incremental net benefits for lock modernization ranging from $128.8 to $238.3 million annually. These positive benefits indicate that the lock modernization alternative is preferable to the WOPC (reactive maintenance) for all forecast scenarios. As with the two proactive maintenance alternatives, the lock modernization alternative is economically better than reactive maintenance.

TABLE 10-13
Lock Modernization Alternative
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$147.8	$237.0	$259.8	$207.0	$233.3
Incremental Costs over Reactive Maintenance	$19.0	$18.6	$21.5	$18.9	$18.4
Incremental Net Benefit	**$128.8**	**$218.4**	**$238.3**	**$188.1**	**$214.9**
Incremental BCR	**7.8**	**12.7**	**12.1**	**10.9**	**12.7**

*Differences subject to rounding error.

10.1.5 Identification of the With-Project Condition (National Economic Development System Investment Plan) for Navigation

1. All three with-project alternatives are carried forward since they are preferable to the WOPC. **Table 10-14** shows the average annual net benefits for the WOPC and all With Project investment alternatives. The lock modernization alternative maximizes net benefits across all traffic forecast scenarios and is thus selected as the with-project condition. The new lock chamber needs along with a more aggressive maintenance strategy will, in the long run, reduce the National Economic Development (NED) costs associated with the operation and maintenance of the heavily vested and economically mature Ohio River mainstem navigation system. The system statistics for the WPC are as shown in **Tables 10-12 and 10-13**.

TABLE 10-14
Average Annual Net Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Alternative	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
WOPC	$2,145	$2,274	$2,252	$2,329	$2,360
AMA	$2,265	$2,368	$2,424	$2,435	$2484
RMA	$2,270	$2,405	$2,435	$2,448	$2,500
LMA	**$2,283**	**$2,492**	**$2,490**	**$2,517**	**$2,575**

2. The system WPC is a mixture of structural improvements (new lock chambers), operational measures (helper boats and N-up/N-down lockage policy during closures), and maintenance alternatives (reactive, advanced and rehabilitation). The optimum lock size at EDM is a 600' chamber for four of five traffic forecast scenarios. Only in the NAQQS traffic forecast scenario is a 1200' new chamber recommended at Montgomery.

3. As expected, delays at individual locks and diverted tonnages are less than in the WOPC (discussed in Section 8.7.1.4). At EDM, the results are dramatic. At Montgomery, the average annual delay times fall to between 1.5 and 2.0 hours per tow after a new main lock chamber is constructed, compared to average annual delays of over 10 hours per tow throughout the planning horizon in the WOPC. Furrther, with a new main chamber and larger auxiliary chamber, the average delays are about constant throughout the analysis period (i.e. there are no spikes due to chamber closures). Diverted traffic is reduced to near zero for most years of the planning period in the WPC, compared to 0.5 – 2.0 million tons diverted annually in the WOPC after 2020. At Racine, delays are comparable to the WOPC in the early years of the planning period, but significant reductions in delays are seen beyond 2050. The average annual delays are held to an hour or less on average per tow throughout the entire analysis period in the WPC, typically about 0.5 – 1.0 hours less per tow per year than in the WOPC until 2050, when the reductions in delays increase to 10 hours or more. However, as in the WOPC, annual delays reach about 4 or 5 hours per tow during years of scheduled component replacements or major rehabilitations. Diverted tonnaged is reduced to about 0.1 – 0.2 million tons for all years of the analysis period in the WPC, compared to about 0.2 – 1.0 million tons annually in the WOPC. See Section 10.2.3.3 for additional discussion of diverted traffic from a system perspective.

4. The findings in this draft report make clear the need for future maintenance and investment in the Ohio River. The recommended investments presented here encourage directing scarce resources to optimize maintenance at existing Ohio River projects and conducting timely feasibility level analysis on the upper Ohio.

5. Specific maintenance and lock construction at each lock and dam and the optimum timings in the WPC are described below.

10.1.5.1 With-Project Strategy By Project

1. **Tables 10-15 – 10-31** show the project-level investments included in the Navigation SIP. All years represent the start of the investment process; a process that can take several years, depending on the investment. Advanced component replacement can take 1-3 years, chamber rehabilitation 3 years, 600' lock replacement 7 years and 1200' lock replacement 8 years. Each of the recommended investments will require additional up-front time for the required analysis leading to an action or authorization.

2. Significant findings include: new lock chambers are recommended at Emsworth, Dashields and Montgomery to replace the existing auxiliary chambers. Main chamber rehabilitations are recommended at all other mainstem projects except McAlpine and New Cumberland where auxiliary chamber rehabilitation is recommended. A reliable main chamber displaces the need for auxiliary lock extension under the current traffic forecast scenarios. Reactive maintenance or component replacement strategies complement the Navigation SIP.

3. **Table 10-15** shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Emsworth is economically justified immediately in the study period (2010). The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Emsworth and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-15
Emsworth Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	**2038**	**2016**	RM	**2050**
Land Wall	**2012**	RM	**2014**	RM	RM
Middle Wall	**2011**	RM	RM	RM	RM
Upper Guide Wall	RM	RM	RM	RM	RM
Lower Guide Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	**2010**	**2010**	**2010**	**2010**	**2010**
Electrical Systems	New 110 x 600	New 110 x 600	New 110 x 600	New 110 x 600	New 110 x 600

* Main Chamber is only used when the new 600' Aux is closed for maintenance. This is the reason for leaving the chamber in the reactive maintenance mode. If repairs are needed they will be made while the new lock is open.

4. **Table 10-16** shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Dashields is economically justified immediately in the study period (2010). The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Dashields and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-16
Dashields Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	**2035**	RM	RM
Land Wall	**2013**	RM	**2010**	RM	RM
Middle Wall	RM	RM	RM	RM	RM
Upper Guide Wall	RM	RM	RM	RM	RM
Lower Guide Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Electrical Systems	**2011**	**2010**	**2010**	**2010**	**2010**
Upper Guard Wall	New	New	New	New	New
Lower Guard Wall	110 x 600	110 x 600	110 x 600	110 x 600	110 x 600

5. **Table 10-17** shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Montgomery is economically justified immediately in the study period (2010) in four of the five forecast scenarios. In the NAAQS growth forecast scenario, a 1200' x 110' replacement of the auxiliary chamber is optimum. The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Montgomery and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-17
Montgomery Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	**2015**	RM	RM
Hydraulic Systems	RM	RM	**2015**	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	**2017**	**2015**	**2051**	**2035**
Land Wall	**2015**	RM	**2011**	RM	RM
Middle Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	**2010**	**2010**	**2010**	**2010**	**2010**
Electrical Systems	New	New	New	New	New
River Wall	110 x 600	110 x 600	110 x 1200	110 x 600	110 x 600

* Main Chamber is only used when the new 600' Aux is closed for maintenance. This is the reason for leaving the chamber in the reactive maintenance mode. If repairs are needed they will be made while the new lock is open.

6. **Table 10-18** shows the need to replace auxiliary miter gates at New Cumberland ranges from 2034 to 2039 depending on the traffic forecast scenario. Since the cost of replacing both sets of miter gates exceeds the $10.6 million threshold when considering fabrication, delivery, assembly, painting, and installation, it is listed as a major rehab. The table also shows economically justified proactive component replacement of the electrical systems in two forecast scenarios. Due to the longer term need of auxiliary gate replacement at New Cumberland, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-18
New Cumberland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	**2015**	**2015**	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Upper	**2037**	**2034**	**2034**	**2037**	**2037**
Miter Gate Lower	**2038**	**2035**	**2034**	**2038**	**2038**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

7. **Table 10-19** suggests the need at Pike Island to rehab the main chamber miter gates and electrical systems in the 2015-2016 timeframe. Other component replacements show traffic forecast sensitivity. The draft ORMSS SIP recommends a near-term major rehabilitation study of the main chamber miter gates and electrical systems at Pike Island and continued monitoring of traffic forecasts and other component reliability to optimize future investments.

TABLE 10-19
Pike Island Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates Upper	**2016** Rehab	**2015** Rehab	**2015** Rehab	**2016** Rehab	**2015** Rehab
Miter Gates Lower					
Electrical Systems					
Miter Gate Machinery (Upper and Lower)	RM	RM	**2014**	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Upper	RM	**2052**	**2052**	**2057**	**2056**
Miter Gate Lower	**2058**	**2053**	**2053**	**2058**	**2056**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

8. **Table 10-20** shows the need to rehabilitate the main chamber miter gates and miter gate machinery at Hannibal ranges from 2011 to 2012 depending on the traffic forecast scenario at this stage of study. The table also shows economically justified proactive auxiliary miter gate replacement way out in 2065 in one forecast scenario. Due to the immediate need of main chamber rehabilitation at Hannibal, immediate action to begin a major rehabilitation study is recommnended along with continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-20
Hannibal Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2012**	**2011**	**2011**	**2012**	**2011**
Miter Gate Machinery (Upper and Lower)	Rehab	Rehab	Rehab	Rehab	Rehab
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate (Upper and Lower)	RM	**2065**	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

9. **Table 10-21** shows the need to rehab the main chamber miter gates and electrical systems at Willow Island ranges from 2027 to 2028 depending on the traffic forecast. Such timing suggests a more intermediate need. The finding at Willow Island leads the draft ORMSS SIP to recommend continued monitoring of traffic forecasts and component reliability at Willow Island to optimize future investments.

TABLE 10-21
Willow Island Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2027**	**2027**	**2027**	**2027**	**2028**
Electrical Systems	Rehab	Rehab	Rehab	Rehab	Rehab
Hydraulic Systems	RM	RM	RM	RM	RM
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

10. **Table 10-22** shows the need to rehab the main chamber miter gates, miter gate machinery, and electrical systems at Belleville in four of five traffic forecasts. The findings at Belleville lead to a draft ORMSS SIP recommendation of preparation for main chamber major rehabilitation project to begin study within the next 7 years and continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-22
Belleville Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2032**	**2017** Rehab	**2017** Rehab	**2017** Rehab	**2028** Rehab
Miter Gate Machinery (Upper and Lower)	RM				
Electrical Systems	**2010**				
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

11. **Table 10-23** shows the need at Racine to rehab the main chamber miter gates, miter gate machinery, and electrical systems in 2019 -2020. The relatively robust finding at Racine leads to a draft ORMSS SIP recommendation of continued monitoring of traffic forecasts and component reliabilities at Racine, in the near term with the intent of starting a major rehabilitation analysis in the medium term to optimize investments.

TABLE 10-23
Racine Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2020** Rehab	**2019** Rehab	**2020** Rehab	**2019** Rehab	**2019** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	**2050**	**2054**	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

12. **Table 10-24** shows the need to rehabilitate the main chamber miter gates and electrical systems at Byrd ranges from 2030 to 2045 depending on the traffic forecast scenario. Such a broad range of timing suggests more uncertainty and because of the less robust finding at Byrd Locks continued monitoring of traffic forecasts and component reliability at Byrd to optimize future investments is recommended.

TABLE 10-24
Byrd Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2055**	**2044**	**2045**	**2030**	**2033**
Electrical Systems	**2024**	Rehab	Rehab	Rehab	Rehab
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Auxiliary Chamber					
Electrical Systems	RM	RM	RM	RM	RM

12. **Table 10-25** shows the need at Meldahl to rehab the main chamber miter gates, miter gate machinery, and electrical systems ranges from 2010 to 2013 depending on the traffic forecast scenario. Also, main chamber hydraulic systems shows economic justification in two traffic scenarios. The auxiliary chamber gates show economic justification for proactive replacement in all traffic scenarios. Since the cost of replacing both sets of miter gates would exceed $10.6 million when fabrication, delivery, assembly, painting, and installation is considered, this also qualifies as a major rehab. Given the relatively robust findings at Meldahl, the draft ORMSS SIP recommends starting both a main chamber and auxiliary major rehabilitation analysis at Meldahl while continuing to monitor traffic forecasts and component reliability of the main hydraulic systems order to optimize future investments.

TABLE 10-25
Meldahl Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2013** Rehab	**2010** Rehab	**2010** Rehab	**2010** Rehab	**2010** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems	RM	RM	RM	**2020**	**2015**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	**2010**	**2010**	**2010**	**2012**	**2010**
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	**2058**

13. **Table 10-26** shows immediate need at Markland to rehab the main chamber miter gates and culvert valves in three of the five traffic forecast scenarios. The table also shows a long term need (2052) to do similar rehab work on the auxiliary chamber in one forecast scenario. Markland findings also show justification for proactive component replacement to be traffic forecast sensitive. Given the relatively robust findings at Markland, the draft ORMSS SIP recommends an immediate main chamber major rehabilitation analysis at Markland that includes the economically justified main chamber component replacements while continuing to monitor traffic forecasts and component reliability of the auxiliary lock components to optimize future investments.

TABLE 10-26
Markland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Base High
Main Chamber					
Miter Gates (Upper and Lower)	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valves	**2013**	**2013**	Rehab	Rehab	Rehab
Miter Gate Machinery (Upper and Lower)	RM	**2023**	**2024**	**2015**	**2015**
Electrical Systems	**2016**	**2016**	**2013**	**2013**	**2013**
Hydraulic Systems	**2036**	**2022**	**2020**	**2016**	**2016**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	RM	RM	RM	RM	**2052**
Culvert Valves	RM	RM	RM	**2045**	Rehab
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

14. **Table 10-27** shows economic justification at McAlpine for proactive replacement of main chamber culvert valves in 2010 and hydraulic systems in 2028-2030. Given this finding, close monitoring of main chamber culvert valve performance at McAlpine and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments is recommended.

TABLE 10-27
McAlpine Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Hydraulic Systems	**2030**	**2030**	**2030**	**2030**	**2028**
Culvert Valves	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valve Machinery	RM	RM	RM	RM	RM

15. **Table 10-28** shows the need at Cannelton to rehab the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, and culvert valves ranges from 2016 to 2017. Based on this finding at Cannelton, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability of the main chamber until such time a main chamber major rehabilitation analysis is warranted.

TABLE 10-28
Cannelton Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2017** Rehab	**2017** Rehab	**2016** Rehab	**2017** Rehab	**2017** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems					
Culvert Valves					
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

16. **Table 10-29** shows the need at Newburgh to rehab the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, and culvert valves ranges from 2016 to 2025 depending on the traffic forecast scenario. Based on this finding at Newburgh, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability of the main chamber until such time a main chamber major rehabilitation analysis is warranted.

TABLE 10-29
Newburgh Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2025** Rehab	**2016** Rehab	**2016** Rehab	**2016** Rehab	**2016** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems					
Culvert Valves					
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

17. **Table 10-30** shows the need at Myers to rehabilitate the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, culvert valves and culvert valve machinery ranges from 2011 to 2014 depending on the traffic forecast scenario. Based on this finding at Myers, near term preparation of a main chamber major rehabilitate analysis while continuing to monitor traffic forecasts and component reliability of the main chamber to ensure optimal investment timing is recommended.

TABLE 10-30
Myers Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2014** Rehab	**2011** Rehab	**2013** Rehab	**2013** Rehab	**2013** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Culvert Valves					
Culvert Valve Machinery					
Hydraulic Systems					

18. **Table 10-31** suggests the need to replace or totally rehabilitate the culvert valves of both chambers at Smithland in the near term. The table also suggests a long term need to replace miter gates. The finding at Smithland means the draft ORMSS SIP will recommend continued monitoring of component reliability in the short run at Smithland until such time the need for a component replacement becomes clearer.

TABLE 10-31
Smithland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	RM	**2054**	**2052**	**2054**	**2048**
Culvert Valves	**2013**	**2013**	**2013**	**2013**	**2013**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	**2055**	**2050**	**2049**	**2050**	**2051**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

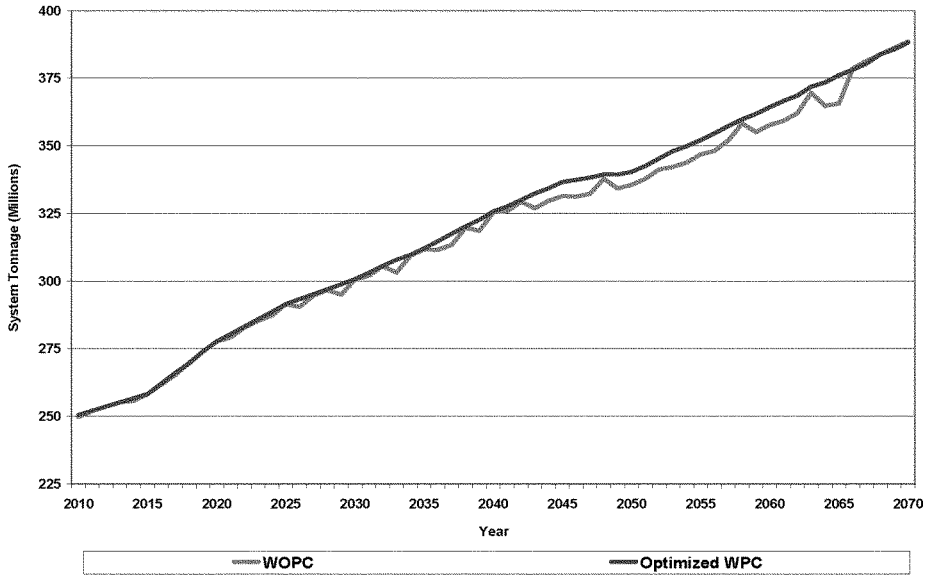
10.1.6 With-Project Condition System Statistics

The with-project condition (WPC) contains a combination of structural improvements and operational and maintenance strategies to optimize Ohio River mainstem navigation for the next 60 years. This sub-section compares WPC system statistics to WOPC system statistics.

10.1.6.1 Equilibrium System Tonnage

Figure 10-3 displays equilibrium system traffic accommodated in the WOPC and WPC. The gap represents incremental diverted traffic between the WOPC and WPC. Over the period of analysis, an average of 2.9 million tons of additional commercial traffic is diverted each year in the WOPC. This additional diverted traffic would challenge overland carrying capacity and increase congestion, traffic accidents, and pollutant emissions.

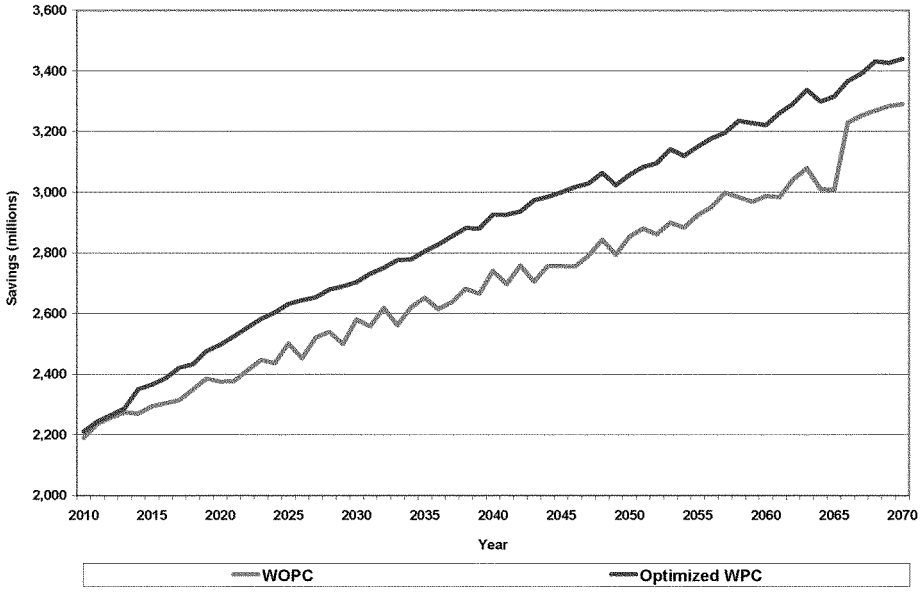
FIGURE 10-3
Equilibrium System Traffic
Average of 5 Forecasts
(Million Tons)



10.1.6.2 System Savings

Figure 10-4 displays system transportation savings averaged over all 5 traffic forecast scenarios for the optimized WPC and WOPC. Equilibrium transportation savings represent system benefits in accordance with ER 1105-2-100. The gap represents incremental system benefits attributable to the more aggressive maintenance and new construction associated with the optimized WPC.

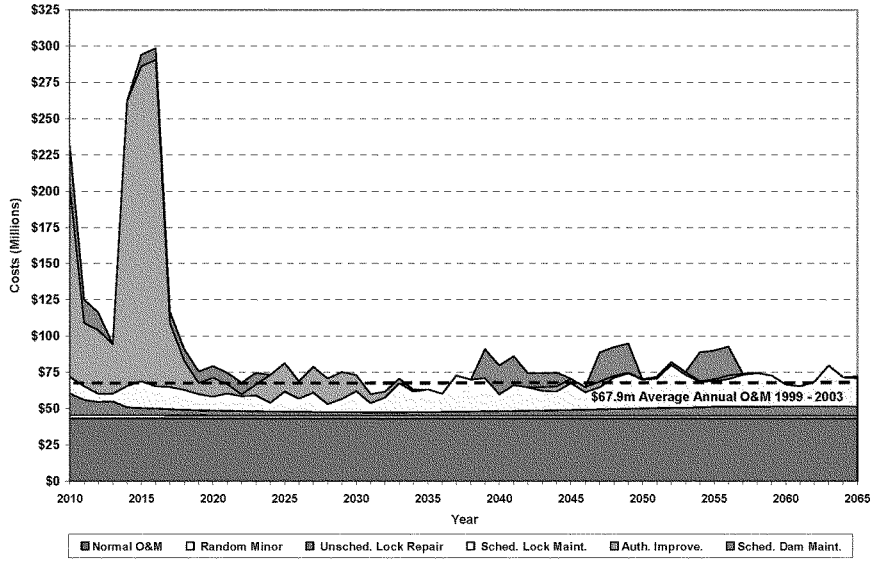
FIGURE 10-4
Equilibrium System Savings
Average of 5 Forecasts
(Million Dollars)



10.1.6.3 System Costs

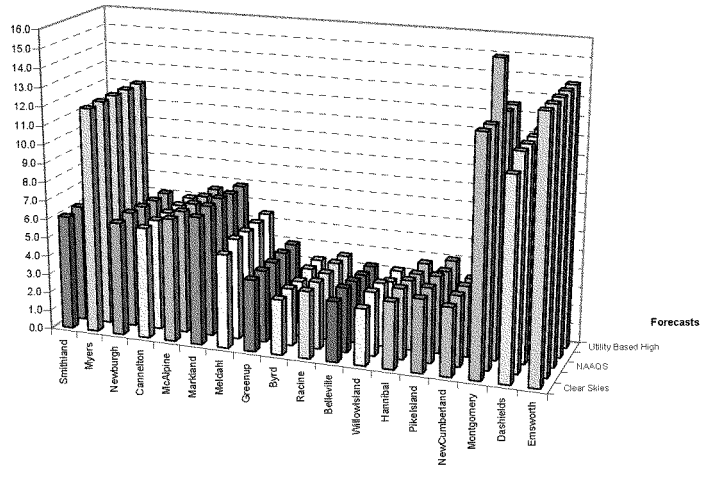
1. **Figure 10.5** shows forecast Federal funding needs over time for the WPC that includes construction of optimum sized locks at EDM and expected unscheduled repair/replacement costs, component replacement, and major rehabilitation costs.

FIGURE 10-5
Total Annual Federal Costs for Ohio River Locks and Dams
With-Project Condition
Average of 5 Forecasts



2. **Figure 10-6** displays the average annual Federal costs for the WPC by project and traffic forecast, including all Federal costs. This large bumps at EDM reflects new construction costs, with the authorized Myers improvement standing out as well and the rehabilitation and maintenance needs at Markland, Meldahl, Hannibal, Willow Island, Pike Island, Newburgh, and Cannelton.

FIGURE 10-6
ORMSS Forecast of Annual Federal Costs
at Ohio River Locks and Dams
With-Project Condition

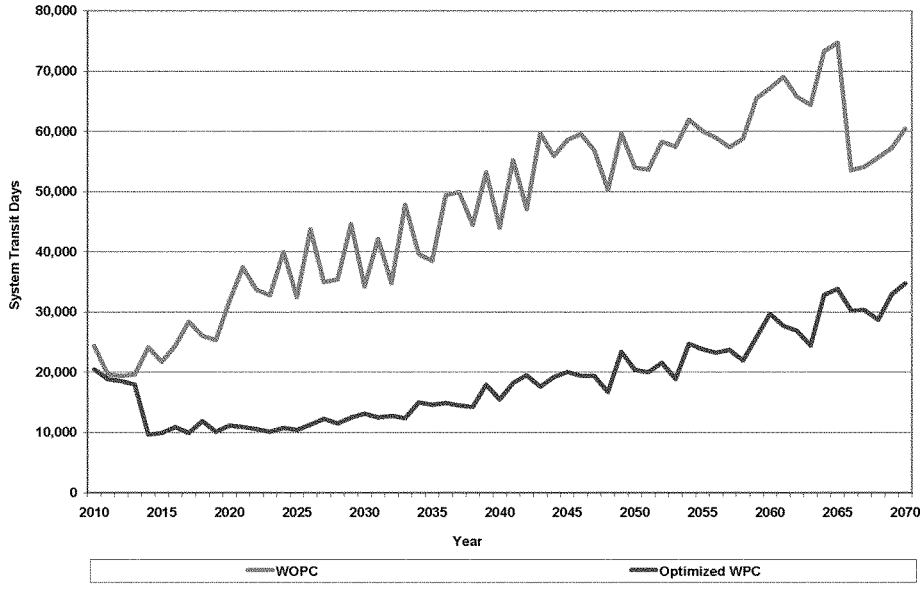


10.1.6.4 System Transit Days

1. **Figure 10-7** compares system equilibrium traffic transit time (averaged over all five traffic scenarios) between the WOPC and WPC alternatives. With-project benefits are derived from a more efficient transportation system because of improved reliability and increased capacity. Capacity increases with fewer closures and the newer, larger chambers. System downtime also decreases. The lower-river rehabilitations and upper-river new lock chambers reduce total system transit days relative to the WOPC.

2. The drop in transit days from 2013-2014 in the WPC is due to the new locks at EDM and the main chamber rehabilitations at Markland, Hannibal, Meldahl, Myers, and Pike Island all coming on-line. The volatility in transit days seen in the WOPC curve results from the unreliability and more frequent scheduled closures found with the reactive maintenance strategy.

FIGURE 10-7
Transit Days to Accommodate Equilibrium Traffic
(WOPC vs. WPC)
Average Of 5 Forecasts



10.2 ENVIRONMENTAL CONSEQUENCES

This is a programmatic EIS and the environmental consequences discussed in this section are discussed from a system-wide perspective. Future NEPA documents for site specific actions would be tiered from this programmatic EIS.

10.2.1 Impacts of WOPC and WPC Alternatives on Major VECS

1. The six major VECs identified during the ORMSS scoping process and emphasized in the CEA Appendix are: water and sediment quality, fish, mussels, riparian resources, recreation, and health and safety. This section summarizes impacts on the VECs under both the WOPC and WPC. Additional details on impacts are presented in **Tables 8-9** and **9-12** and in the accompanying text in subsections 8.7.2 and 9.7.1, respectively. Also, specific traffic and construction related issues identified that have potential environmental impacts are discussed in 10.2.3.

2. Under the WOPC alternative and its three maintenance options (routine, cyclical and unscheduled repairs), general short-term detrimental effects would include increased water turbidity, interference with upstream movement of fish, disruptions in downstream mussel habitat, damage to riparian resources due to the queuing of tows and their bank toe-ins and tie-offs, and disruption of recreational boat lockages. Of the three maintenance actions, unscheduled repairs are potentially the most disruptive and detrimental to all major VECs. Emergency repairs under extraordinary conditions, including the failure of major lock components, preclude opportunities to avoid or minimize environmental impacts while increasing impacts from queuing and construction site activities. In such cases, any mitigation or restoration of environmental damages would occur after-the-fact. The duration of emergency conditions and the time of the year they occur would influence the extent of the impacts.

3. Two of the three options under the WPC alternative – the advanced maintenance alternative (AMA) and major rehabilitation alternative (MRA) – have short-term, localized impacts that are similar to those in routine or cyclical maintenance under WOPC. However, more pronounced impacts would occur in the lock modernization alternative (LMA), primarily because of extensive dredging and excavation impacts and the permanent loss of aquatic habitat within the project footprint. Further, placement of fill materials around the foundations of lock walls and alternations in flow patterns could cause siltation of fish and mussel habitat. Clearing of riparian areas would reduce habitat and also may alter local hydrological patterns; revegetation and restoration of function in such areas may take decades. A positive aspect of LMA is that its long-term planning horizon may offer opportunities to enhance environmental sustainability (ES) during construction of new structures or adaptations of older ones. Enhancement could include incorporation of desired ES outcomes into the design of new or modified infrastructure. Examples could include fish passage or facilities to increase dissolved oxygen.

4. The long-term perspective of the ORMSS process requires consideration of impacts beyond those caused by the individual maintenance, repair or modernization activity. While short term impacts of less aggressive WOPC maintenance are localized and relatively brief, especially under routine and cyclical maintenance, WOPC maintenance approaches do not address the long-term, negative effects of barge queuing. In fact, as navigation infrastructure ages and traffic increases throughout the ORMSS planning horizon, more unscheduled repairs would be expected to occur, compounding the impacts of queuing on aquatic and riparian resources.

5. In contrast, more aggressive maintenance, including the three projects associated with the LMA, incurs more pronounced environmental impacts during implementation. However, these improvements would provide for long term reductions of such impacts as a result of more efficient and reliable handling of both commercial and recreational river traffic accompanied by reductions in queuing and its detrimental impacts.

6. Impacts to the Health and Safety VEC under the AMA and MRA would be similar to those under the Reactive Maintenance alternative of the WOPC. The duration of risks during individual projects will be longer, especially under the MRA, but the

frequency of such events would be reduced. In contrast to AMA and MRA, the LMA option involves a longer time period of more intensive activity and, therefore, greater risk of accident and injury during the lock construction projects. The need to conduct emergency repairs, sometimes under intensive and higher-risk conditions, may occur under any of the alternatives, but is likely to be experienced most frequently in the WOPC. Under any alternative, strict adherence to proactive safety measures is essential to minimize worker accidents and injuries. In the long-term, alleviating congestion by providing more efficient vessel passage through modernized locks would have beneficial safety effects for both commercial and recreational vessels.

10.2.2 Cumulative Effects

10.2.2.1 Approach To Analyzing Cumulative Effects

1. Environmental issues are addressed in a Cumulative Effects Assessment (CEA) study of the entire mainstem navigation system (see **Environmental Appendix**). This strategic-level impact study provides a holistic review of the past, current, and anticipated environmental impacts from multiple actions and programs of the Corps of Engineers; other Federal, state, and local governmental agencies; and private industries and agricultural activities. The CEA study forms the technical basis for this programmatic environmental impact statement (PEIS). This section provides an overview of the CEA findings. For a detailed discussion of the CEA methodology and findings, see Cumulative Effects Assessment in the Environmental Appendix.

2. Cumulative effects (CEs) are an emerging issue, in general, in impact studies; the definition that follows is in the Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) Regulations (Council on Environmental Quality, 1978):

> "Cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

3. This CEA study is in consonance with the above definition and with the policy of the U.S. Army Corps of Engineers relative to addressing the cumulative effects of water resources plans such as the SIP. This policy is (U.S. Army Corps of Engineers, 1999):

> The cumulative effects of the plan and other similar activities should be analyzed. Each proposed water resource development activity is but a piece of a large-scale program. The combined beneficial and adverse economic, environmental and social impacts of individual projects, each of which may be

relatively minor, can have a significant regional or national impact. At each level of the evaluation and review process it is necessary to assess the cumulative beneficial and adverse effects of individual project impacts. Significant effects should guide the decisions.

4. Within the CEA, the use of Environmental Sustainability (ES) as an "ultimate test" for determining the significance of cumulative effects was used. ES is identified in the Corps' recently published Environmental Operating Principles (EOPs) as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations" (U.S. Army Corps of Engineers, 2002).

5. The ES categories of the various environmental resources or Valued Environmental Components (VECs) included in the CEA are derived by combining the best professional judgment of the Corps Project Delivery Team and Interagency Working Group (IWG) members with the cumulative effects of multiple actions as manifested through information available on indicators selected for each VEC. Although ES categories are somewhat qualitative, they are based on thorough analyses of past and present conditions as well as future conditions related to trends, plans, laws, regulatory programs and other sources of information that are beyond mere speculation.

6. Categories of ES were determined for the past, present, and future of each VEC. Specific ES categories were developed for each VEC and are found in the corresponding CEA chapters. The general template for the ES categories follows:

- Not sustainable (NS) – The composite conditions of the selected indicators do not reflect conditions that can sustain the resource long-term.

- Marginally sustainable (MS) – The composite conditions for the selected indicators are such that the resource can be sustained for the majority of river miles in or along the Ohio mainstem, but conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences.

- Sustainable (S) – The composite conditions of the selected indicators reflect sustainability for essentially all the river miles in or along the Ohio mainstem. Further, conditions of the indicators exceed regulatory thresholds and pertinent governmental programs are in place to support the resource.

10.2.2.2 Environmental Sustainability Conclusions By Valued Environmental Component

1. Applying this methodology to each Valued Environmental Component (VEC) in the CEA resulted in past, present, and future characterizations of ES that were included in bar graphs accompanied by synopses of conditions. Because of implementation of

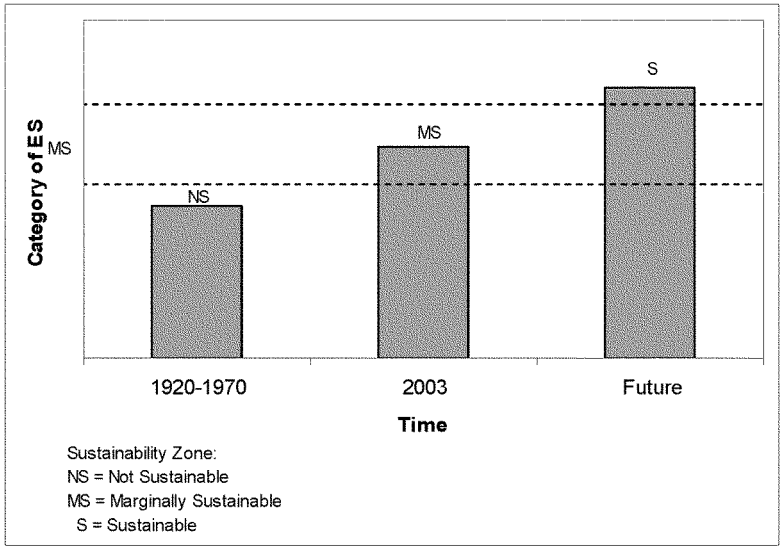
important legislation or the quality of information available, more than one ES category may be used to categorize past conditions.

2. The following sections present the ES graphs (**Figures 10-8 through 10-18)** and their respective synopses which form the basis for additional conclusions related to interactions among VECs, overall cumulative effects, and sustainability of the Ohio River mainstem.

A. Water Quality and Sediment Quality

1. Prior to 1920, and continuing up to about 1950, the water quality of the mainstem was in a degraded state characterized by low DO concentrations, low pH levels in the upper river, high bacterial contamination, high nitrogen concentrations, and remobilization of potentially toxic chemicals that had become associated with river sediments. Essentially no pollution reductions or controls programs, or regulatory programs, were in place during this period. Further, declines in the diversity and health of fish communities in the mainstem had occurred. Accordingly, the ES of water quality was classified as "not sustainable". Primary contributors to these conditions were the largely untreated and uncontrolled point and non-point pollutant discharges from growing municipalities and various types of industries and land uses along the river.

FIGURE 10-8
ES of Water Quality



2. Due to the programs of ORSANCO, and requirements of the Federal Water Pollution Control Act (and the amended Clean Water Act), the water quality of the Ohio River has shown a steady improvement in recent decades. For example, DO concentrations are typically above the 5.0 mg/L standard, pH levels are between the 6.0 to 9.0 standard, and nitrogen concentrations meet current water quality criteria. However, continuing concerns include bacterial contamination primarily associated with non-point source pollution downstream from major urban areas, legacy "contaminated sediments" in the upper Ohio River, and fish consumption advisories throughout the mainstem. In contrast, the results of algae (plankton) and aquatic macroinvertebrate surveys in recent decades have demonstrated steady improvements in these resources, which parallel water quality improvements. As of 2003, 779 of 981 miles (~80%) of the mainstem are "fully supporting" aquatic life, and 949 miles (~97%) are "fully supporting" public water supply use. None of the mainstem was "fully supporting" fish consumption due to consumption advisories along its total length. For contact recreation, 269 miles (~27%) are "fully supporting", with major impairment continuing from combined sewer systems in urban areas. Overall, the implementation of the National Pollutant Discharge Elimination System (NPDES) permit programs by USEPA under the Clean Water Act for municipalities, industries, and stormwater has led to the reduction of discharges into the mainstem. Initiatives for increasing the use of "Best Management Practices" (BMP) have also been established. Further, the diversity and health of fish communities along the mainstem has considerably improved. Accordingly, at this time, although there are many positive signs, the ES of the water quality VEC is classified as "marginally sustainable".

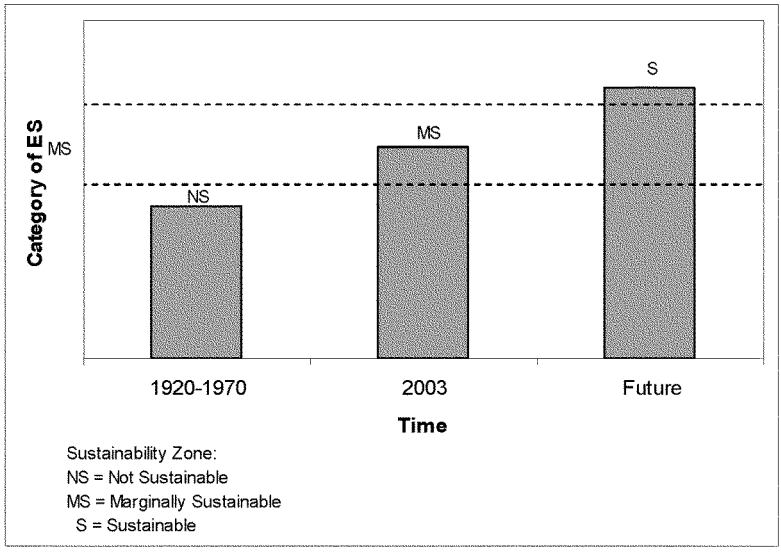
3. Regarding the future, it is expected that water quality of the Ohio River mainstem will further improve with continuation of source control and other pollution reduction programs, and implementation of the Ohio River Ecosystem Restoration Program and other remediation efforts. NOTE: The Ohio River Ecosystem Restoration Program has yet to receive Congressional Appropriations and is now a candidate for de-authorization. However, it is anticipated that the ES of water quality will achieve a "sustainable" condition. Vigilant efforts are still needed to continue effective water quality and aquatic ecological monitoring and management efforts. In this regard, it may be desirable to plan and implement source monitoring programs for selected actions considered of high importance relative to cumulative effects. Further, special surveys for legacy-contaminated sediments are needed along with site-targeted efforts to reduce bacterial pollution from combined sewer overflows (CSOs). Reasonably foreseeable future actions expected to be beneficial to water quality in the future include implementation of nonstructural navigation improvements and technological improvements related to communications and more environmentally-advanced barge design. Activities that support commercial navigation (e.g., port development and maintenance dredging) will continue to be scrutinized by regulatory agencies and Non-Governmental Organizations and may be more strictly regulated. Some redevelopment activity may revive underused urban space or industrial brownfield areas, with possible long-term water quality benefits related to clean up. Much development activity, however, will involve conversion of existing floodplain lands that now afford habitat protection, open space and ecosystems values. Once converted, such lands are unlikely to revert to their former more natural states. Increasing emphasis on pollution prevention, erosion control BMPs, and implementation of the Phase 1 and 2 NPDES storm water programs could counteract some adverse impacts, particularly in more urban areas. In general, several regulatory initiatives in recent years should measurably improve water and sediment quality, but it is not possible to predict the magnitudes of their beneficial effects.

B. Fish Resources

1. Prior to1920 and continuing well into the mid-20th century, fish communities became degraded, as reflected in the decline of many native species and the increase in pollution tolerant species. This decline was particularly pronounced in the upper and middle river, where human populations grew rapidly during the first half of the 20th century, leading to increased inputs of domestic sewage, industrial effluent, and acid mine drainage. Numerous other actions contributed to the degradation of fish communities, including land clearing and sedimentation beginning in the 19th century; impoundment of the river by navigation dams that disrupted migrations of several important river fishes; in-stream sand and gravel dredging; development of new ports, terminals and marinas; introduction of the common carp, and increasing quantities of stormwater runoff from urbanizing areas. Because these actions contributed to habitat loss, changes in species composition and abundance, and serious declines in necessary water quality conditions, the ES for this period is classified as "not sustainable". Further, until 1948, when a limited precursor of the Clean Water Act was passed and the ORSANCO interstate compact was signed, pertinent laws were limited. Accordingly,

based on scientific data indicating changes in fish communities as well as the recognition of multiple actions and factors causing such changes, it was concluded that the composite conditions for the selected indicators of ES for fish communities did not reflect conditions that would sustain diverse, healthy fish populations throughout the river.

FIGURE 10-9
ES of Fish Communities



2. From the mid-20th century until the present time, improvements in sustainability of fish resources have been observed throughout the mainstem. Such improvements have resulted primarily from initiatives by ORSANCO, efforts of the six Ohio River states, and the requirements of the Federal Water Pollution Control Act and the amended Clean Water Act. As municipal wastewater and industrial effluents to the river have improved, and other pollution control measures have increased pH and oxygen while reducing toxins, fish communities of the Ohio River have shown steady improvement, marked by the recovery of many native species. The common carp is no longer as dominant as in the past. Concurrent with improvements in water quality, however, has been the continued inundation of fish habitat not only from navigation structures constructed before 1950, but also from the continued construction and operation of additional high-lift dams. The modern navigation system, combined with land use and flood control practices in the watershed, has caused the inundation and siltation of extensive areas of gravel substrate, preferred by many migratory fishes. Various studies on human impacts on Ohio River fishes, including studies on winter habitat and fish passage, underscore the need for additional research and development of resource management practices to gain a more comprehensive understanding of ES of the mainstem fish. Accordingly, the ES of the fish resource at present is classified as "marginally sustainable." Two major uncertainties emerged during the last decade that may affect the fish resource into the

future: 1) the invasion of Asian carps and 2) the invasion and unknown population dynamics of zebra mussels.

3. Regarding the long-term future, the CEA has identified 60 reasonably foreseeable future actions ranked as having high or medium importance to fish. These include actions that change habitat, change disturbance regimes, change hydrological patterns, affect ecological services, and are related to population changes. During recent decades, regulatory requirements and pollution control programs have been implemented that will benefit the fish resource, if continued into the future. Additional tools and studies that also should increase understanding of the ES of fish in the mainstem include the NAVPAT habitat assessment model, the new Ohio River Fish Index (ORFIn), and supplemental fish studies related to §316(a and b) of the Clean Water Act. It is also expected that the Ohio River Fish Management Team, comprised of state agencies along the river, and USFWS' Ohio River Valley Ecosystem Team will continue to be involved in fish resource monitoring and management. Given recent improvements in the resource, the development of new assessment tools, and the level of stakeholder interest, it is expected that fish communities of the Ohio River mainstem will attain a "sustainable" condition and may further improve with long-term elimination of combined sewer overflows and better non-point pollution control. The habitat effects of impoundment of the river are expected to persist into the future, but implementation of ES improvement measures may produce responses that counteract such effects and benefit habitat and enhance interpool connectivity. A possible threat to the resource is the invasion of Asian carps moving upriver. Vigilance by ORSANCO and other resource agencies will be required to assess populations while potential measures to control these species are evaluated for the Ohio and other major river systems in the U.S.

C. Mussels

1. Mussels are part of the river's natural filter system, and they play an important role in the breakdown/compartmentalization of organic matter as well as provide habitat for other invertebrates. To summarize the historical and current status of mussel populations in the Ohio River mainstem, the following observations can be made:

2. Over the last century the number of mussel species has declined from about 80 to the currently reported 54 species. Evidence suggests that the number reached a low in the vicinity of about 25 to 35 species in the 1950s and 1960s. Numerous factors contributed to the decline, including, but not limited to, water pollution from municipalities, industries, and acid mine drainage; instream extractions of sand and gravel; construction and operation of high-lift locks and dams; and disruptions to mussel beds due to barge fleeting areas, queuing, and disposal of dredged materials. Recent increases in the numbers of species can be attributed to water quality improvements, protection efforts related to mussel beds, and natural reintroductions from tributary and/or downstream populations. However, despite these advances, research continues on the unique characteristics of the life cycles of numerous mussel species, and their susceptibility or resiliency regarding natural stresses from dynamic river flows and water quality, and from human-induced stresses associated with economic development

activities. The greatest factor affecting mussels in the mainstem Ohio River is habitat alteration resulting from impoundment by the high lift dams. Maintenance of the navigation pools creates year round slackwater habitat which has had and continues to have the most significant adverse affect on mussel resources.

3. The lower portion of the river was not as severely affected by historical water quality degradation as the upper river. As a result, the lower river typically had and continues to support more diverse mussel populations and generally higher densities than the upper river. However, concerns currently exist relative to fluctuating populations of invasive zebra mussels and continued re-introduction of zebra mussels attached to barges. Also, recent invasions by asian carps, especially black carp, is a cause for further concern. Thus there is a need for additional research on the interactive relationships between the invasive species and native mussels and their associated life cycle, including fish hosts.

4. As more information is assembled on the locations and characteristics of mussel beds in the mainstem, the planning and implementation of targeted and long-term mussel monitoring programs can be more effectively accomplished. Further, the results can be used in an ecosystem restoration program focused on enhancing and maintaining the ES of the mussel resource.

5. Based upon the above-described affected environment conditions, and consideration of multiple actions and their effects, the ES of mussels of the mainstem of the Ohio River can be characterized and depicted as follows:

6. In the time period from 1920, and continuing up to the mid-point of the last half of the 20th century, the ES of freshwater mussels in the mainstem was in a continuing decline and thus classified as "not sustainable". The decline in mussel species and densities, and the areal extent of mussel beds, was particularly noted in the upper and middle river segments, with the lower river concurrently experiencing a lesser, but similar decline. Numerous actions contributed to the decline, including, but not limited to, acid mine drainage in the upper river, high-lift locks and dams disrupting mussel and fish-host migration, numerous discharges of untreated to partially treated municipal and industrial wastewaters, in-stream sand and gravel mining, dredging for new ports and terminals, periodic maintenance dredging for the navigation system, mussel harvesting for button manufacturing and the cultured pearl industry, and multiple land use changes resulting in increased non-point source pollution. These actions and others contributed to losses in quality mussel habitat throughout the river, declines in necessary water quality conditions, and disruptions in various components of the mussel life cycle. Additional contributing factors to this decline included the limited information on the life cycle requirements of several mussel species and poor understanding of the influence of timing of interpool movement of fish on mussel reproduction. Further, there was limited recognition of the biological importance of mussels, and limited existence of environmental and resource protection laws up to 1948 (when a limited precursor to the current Clean Water Act, the Federal Water Pollution Control Act, was passed) and 1973 (when the Endangered Species Act was passed). Accordingly, as a result of the scientific

data indicating declines in various mussel populations in the mainstem, as well as the recognition of multiple actions and factors causing such declines, it was concluded that the composite conditions for the selected indicators of ES for mussels did not reflect conditions that would sustain diverse, healthy populations of freshwater mussels throughout the river.

7. In the time period from 1975 up to 2003, some improvements in sustainability of the mussel resource in the mainstem have been noted, although improvements are typically localized and exhibit frequent fluctuations. Conversely, there has also been a general reduction in number and aerial extent of previously known mussel beds since about 1975. Improvements that have occurred resulted from 1) reduced acid mine drainage in the upper river, 2) enhanced treatment requirements for municipal and industrial wastewater treatment plant discharges, 3) consideration of mussel bed locations in river-related permitting programs (e.g., Section 404 and Section 10 permits) and navigation system operational features (location of queuing and barge fleeting/storage areas, and placement of dredged material), and 4) protection provided through designation of several mussel species as threatened or endangered under the ESA and similar state protective mechanisms.

8. Recent fish migration research indicates evidence of some inter-pool movement (see fish resources chapter); however, it is not clear if sufficient host fish are able to move successfully from a mussel assemblage in one pool to another mussel assemblage in another pool or that such movement coincides with seasons when host fish would be carrying mussel glochidia. The designation of "marginally sustainable" is appropriate considering that composite conditions for the selected Ecological Sustainability indicators are such that diverse mussel populations are occurring only along some segments and in some pools of the river and that conditions of the indicators are somewhat tenuous both in location and likelihood of occurrence. The conditions also reflect a continuing level of uncertainty regarding appropriate quantitative measures of the Ecological Sustainability of freshwater mussels.

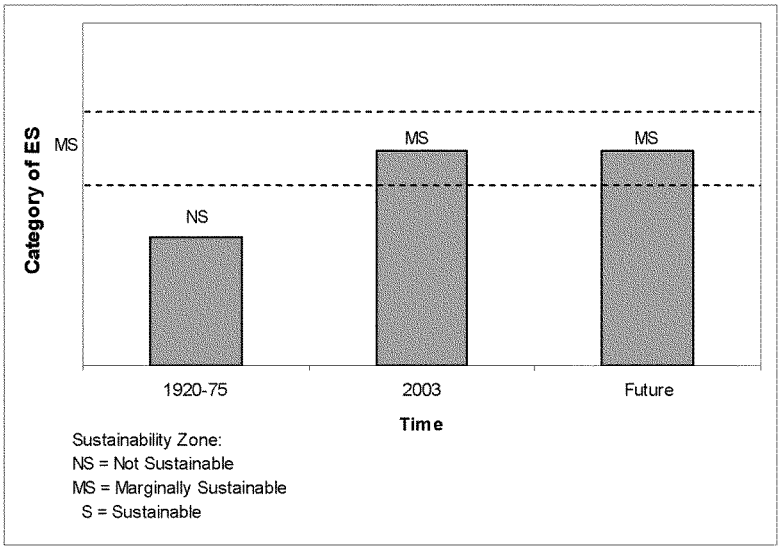
9. Six previously designated endangered species have not been recently found in the mainstem; however, five others have been recorded in the mainstem during this period, but mainly as very old individuals or single individuals. This trend of apparent loss and/or diminishment of listed mussel species during this time period does not bode well for sustainability of mussels in the future. Three additional mussel species (spectacle case, rayed bean, and sheepnose) are currently candidate species in line to be added to this list. The spectacle case is already generally considered extirpated from the mainstem. In addition, the rabbitsfoot mussel has undergone a status review and is now listed as endangered.

10. In contrast to the improvements, concerns still exist regarding the occurrence of non-indigenous species such as zebra mussels and asian carps, especially black carp. The most recent decade has been characterized by expanding databases to include results of scientific studies of freshwater mussels in the Ohio River. These databases, although incomplete, have been used in recent environmental planning and permit programs and

are providing the basis for on-going research efforts into the life cycle of various mussel species. As a result of relatively recent scientific data (since 1990) indicating recruitment and general improvement in some mussel populations in navigation pools in the lower, middle, and some upper portions of the river; the recognition of improvements in water quality and general habitat conditions resulting from various features of the Clean Water Act and Endangered Species Act, and recent fish migration research which indicates evidence of limited inter-pool movement (see Fish Resources), it is concluded that the current ES classification is "marginally sustainable,"

11. Regarding the future, this study has identified 56 types of reasonably foreseeable future actions ranked as having high importance relative to CEs on native mussels, and 14 additional types ranked as having medium importance. These 70 actions include ones that directly or indirectly contribute to mussel habitat degradation and instability, that affect reproductive success and community connectivity, or that are beneficial to mussels (numerous regulatory and educational actions are included in this latter group). As additional regulatory requirements and pollution control programs are implemented, the habitat conditions should be more conducive to reproductive success and community connectivity than at present. Of particular importance is the need to integrate considerations of mussel beds and the life cycle features of mussels into permitting and other locational decisions within or along the mainstem. As further mussel monitoring and research is conducted, these data should be added to databases to provide further information for both protecting and promoting mussels. Further, consideration should be given to implementation of an ecosystem restoration program for Ohio River freshwater mussels. While these actions collectively will not reverse the habitat loss that has occurred, they should aid in recolonization and at least partial restoration of mussel populations in the remaining suitable habitat.

FIGURE 10-10
ES of Mussel Resources



12. This assessment of future marginal sustainability acknowledges that many unknowns remain and that recovery of the Ohio River mainstem native mussel populations will be a long-term process involving many years of collaborative efforts and monitoring. Evidence of recruitment and population stability will be necessary to validate viability. To illustrate the many uncertainties, the following tasks to effect recovery have been selected from a more extensive list from Watters (1994) and supplemented by the ORMSS Interagency Working Group:

- Identify other resource values associated with mussel populations, including fish hosts, key food organisms and habitat elements.
- Protect and manage mussel populations and their habitat on a site-specific basis to avoid future net loss of available habitat or populations.
- Characterize the habitat that best supports species of concern, including historically important sites.
- Restore habitats and reintroduce mussel species to suitable areas.
- Conduct searches for additional populations.
- Enforce all laws and regulations pertaining to collection of specimens and protection of habitat.
- Enhance knowledge of life histories for species of concern, including life histories of host fishes.
- Identify the potential effects and responses to zebra mussel and Asian carps (especially black carp) invasions and their control measures.
- One particular mitigation measure that needs to be evaluated would be the efficacy of removing zebra mussels from vessels to prevent re-infesting areas.

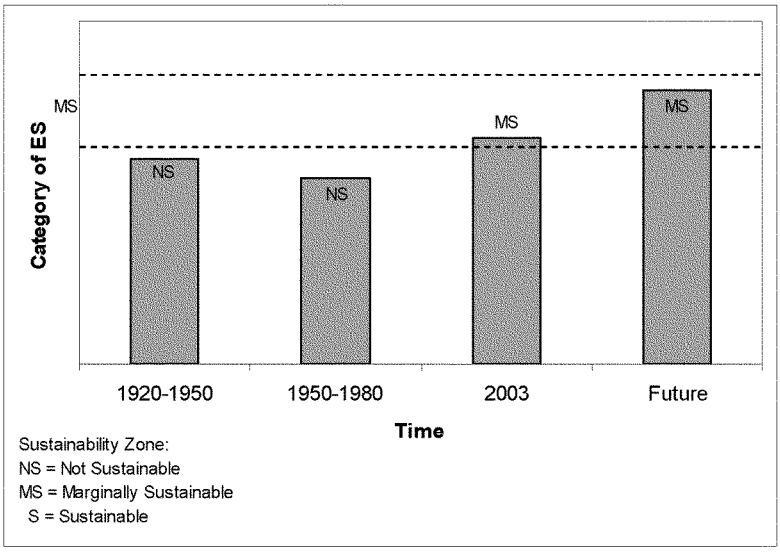
- Increase public and agency awareness of existing laws that protect mussels.
- Use media opportunities to reach the general public and encourage involvement in the recovery process.
- Restore and protect direct connections to tributary populations.
- Restore mobility of fish hosts through dams at appropriate times of the year needed for mussel reproduction.

D. Riparian/Floodplain Resources

1. In the time period prior to 1920, and continuing up to about 1950, the riparian/floodplain resource (RFR) can be classified as "not sustainable" due to relatively rapid losses of riparian habitats and their functions, the lack of knowledge of the importance of these resources to both terrestrial and aquatic ecosystems, and the essential absence of any institutional programs to manage or control riparian areas. Further, the lack of awareness of environmental services performed by RFR, coupled with ongoing floodplain development, especially in the upper and middle river, led to loss and fragmentation of valuable RFR along the Ohio mainstem before such resources could be well-documented.

2. In the time period from 1950 to 1980, worsened "not sustainable" conditions occurred in the first several decades as a result of still more disruptions and losses of riparian areas. However, recent decades have included an increasing awareness of riparian services, including regulation of wetlands, a highly productive riparian component. The establishment of the Ohio River Islands National Wildlife Refuge has focused attention on the disappearance of another riparian habitat type, islands, and has heightened visibility of the riparian resources of the Ohio mainstem embayments. These initiatives suggest the current status of RFR may be moving toward "marginally sustainable". Accompanying these initiatives is an increasing recognition that institutional programs must be established to protect RFR.

FIGURE 10-11
ES of Riparian/Floodplain Resources



3. Regarding RFFAs for these resources, the growing awareness of environmental services performed by RFR, as well as increasing demand for river corridor enhancement and protection for passive recreation may help move RFR toward a more sustainable future. However, it is less certain if environmental regulations and institutional programs will be in place to support RFR sustainability and stem fragmentation and loss of RFR from development along the Ohio River mainstem. Accordingly, the future ES of RFR is classified as "marginally sustainable."

4. An important issue is the need for institutional programs for riparian area management. Examples of such program features include, but are not limited to:

- requiring impact identification and mitigation via the NEPA process..
- designation of special management areas on public lands.
- regulation or other means to discourage activities that further fragment or degrade functional values on privately-owned riparian areas.
- utilization of incentives such as cost-sharing, low-cost loans, or tax reductions to encourage the use of BMPs on riparian areas.
- the purchase of privately owned riparian lands, either in fee or by easement, for public management.

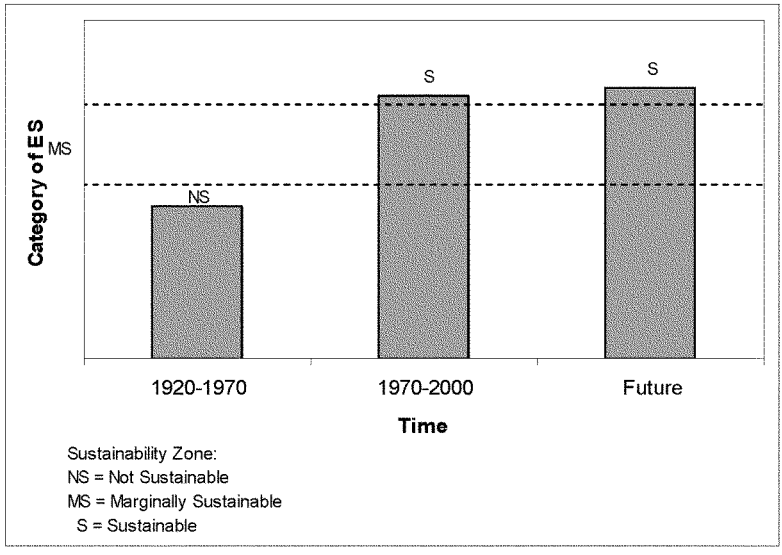
E. Air Quality

1. In the time period prior to 1920, and continuing up to about 1970, air quality of the Ohio River Valley was in a degraded state and thus classified as "not sustainable" due to largely untreated and uncontrolled point and non-point pollutant discharges from coal fired power plants, other types of industries, and vehicular sources.

2. Due to the requirements of the Federal Clean Air Act of 1970 and subsequent amendments, the air quality in the region has shown a steady improvement in recent decades; thus it is currently in a "sustainable" category.

3. Regarding RFFAs for these resources, it is expected that air quality in the Ohio River Valley will further improve as a result of continuation of source control and other pollution reduction programs; thus, it will be maintained in a "sustainable" condition. However, this characterization should not bring complacency; rather, vigilant efforts are still needed to continue effective air quality monitoring and management efforts. Such efforts are reflected in the recent implementation of more stringent standards for ozone and particulate matter and ongoing efforts to establish effective limits for mercury and to continue analysis of the need to control other types of emissions.

Figure 10-12
ES of Air Quality



F. Health and Safety

1. In the time period prior to 1920 and continuing into the 1960-70s, health and safety issues on the Ohio River represented a broad spectrum of risk factors.

Construction and workplace conditions were generally more dangerous than at present; spills and discharges from commercial navigation, river oriented industries, and untreated municipal effluents contributed to a variety of public health risks; and little or no information was available to advise the public of ambient risk levels associated with river oriented activity.

2. While individual risk factors no doubt varied significantly from time to time, most H&S related issues for the period are categorized in **Figure 10-13** as 'marginally sustainable.' However, activities that involved more direct exposure to water quality risk factors are categorized as 'not sustainable' in **Figure 10-14**.

3. Improvements to water quality, reduced risks of spills and faster response, improved workplace safety standards, and effective safety standards for recreational boating have all combined to make the Ohio River a safer place to work, live, and play. These improved present day conditions result in a 'sustainable' classification in **Figure 10-13.** Improved conditions have also contributed to reduce risk factors associated with contact recreation and fish consumption. However, problems associated with continued exceedances of biological standards, the persistence of some contaminants associated with fish consumption, and mixed signals regarding fish consumption standards result in a present time classification of 'marginally sustainable' for these activities.

FIGURE 10-13
Health & Safety for Workplace and Boating Accidents

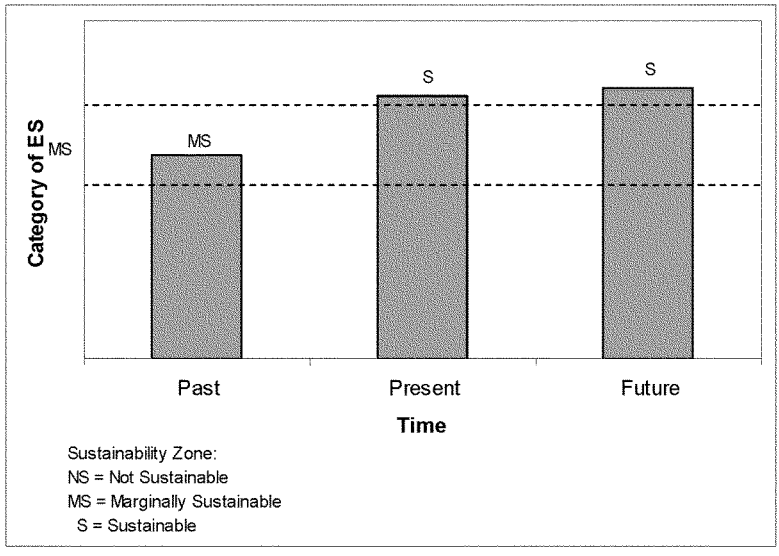
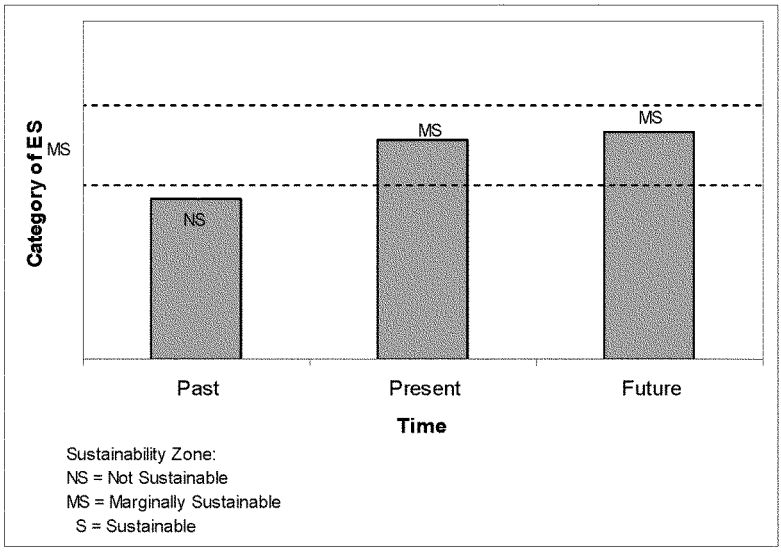


FIGURE 10-14
Health & Safety for Contact Recreation and Fish Consumption



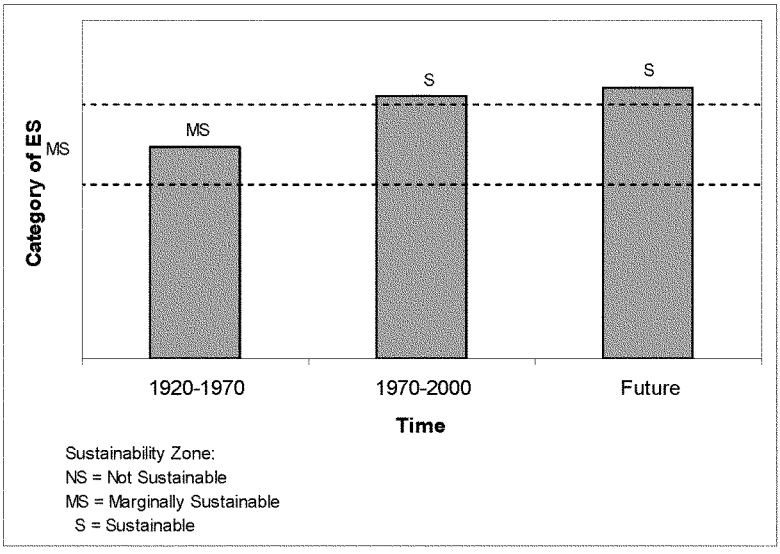
4. With respect to RFFAs, most H&S issues are expected to remain in the 'sustainable' rankings. It is important to note, however, that continued growth of commercial navigation, recreational activity, river oriented industries, and other uses of the river will require continued improvements in management and regulation of H&S issues just to maintain the status quo.

5. While improvement of risk factors associated with contact recreation and fish consumption is expected to continue, these factors are kept in the 'marginally sustainable' category as a conservative estimate of potential trends. Some efforts required for continued improvement, such as rehabilitation of sanitary sewer systems to eliminate CSOs and SSOs or reduction of mercury emissions from coal combustion, will require significant investments and long periods of time to achieve results.

G. Recreation

1. In the time period prior to 1920, and continuing up to about 1950, recreation on the Ohio River occurred in a degraded environment due to largely untreated and uncontrolled pollution discharges from growing municipalities, mining activity, and various types of industries and land uses along the river. Although the river continued to be used for recreation during this period, the overall ES was "marginally sustainable" and may have been "not sustainable" for the worst years of pollution. However, recreation information from the worst decades of pollution is limited as that time period coincided with the Great Depression, World War II, and the post-war period shortly thereafter, when leisure time and financial resources were limited.

Figure 10-15
ES of Recreational Resources



2. At the present time, recreation on the Ohio River is currently in a "sustainable" condition due in large measure to water quality improvements related to ORSANCO programs and requirements of the Federal Water Pollution Control Act (and the amended Clean Water Act). Water quality improvements, combined with increased economic prosperity, have increased the demand for and stimulated the development of marinas, ramps, and other recreation facilities along the river. The recent era of more integrated riverfront planning also has addressed recreation needs and has increased opportunities for an expanded spectrum of recreational choices.

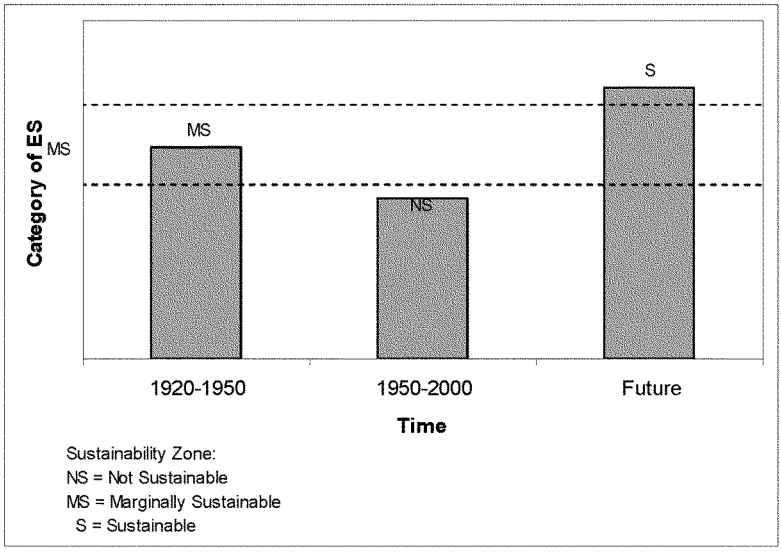
3. Regarding RFFAs for these resources, it is expected that community planning and development of recreation facilities, further water quality improvements, especially in stormwater and CSO management, and habitat protection and restoration efforts will continue to enhance recreation experiences. Socioeconomic projections for a stable or slowly growing population and continued improvement in standard of living would be expected to result in continued growth of demand for recreational opportunity. Consequently, the future ES is classified as "sustainable." Although the perception exists that increased participation could lead to overcrowding and competition for limited resources, it does not currently seem to be an overriding influence affecting people's decisions to participate in river-related activities.

H. Transportation and Traffic

1. In the time period prior to 1920, and continuing up to about 1950, the waterway transportation and traffic system can be classified as "marginally sustainable". This classification is a result of system capacities that tended to exceed demands; however, the system was not particularly cost-effective or efficient, nor was it focused on minimizing externalities.

2. In the time period from 1950 to 2000, "non-sustainable" conditions were often experienced as a result of the construction of new infrastructure, demands that exceeded system capacities at numerous locations, and the use of auxiliary locks during repair and maintenance periods. In fact, due to the aging infrastructure, it can be anticipated that the "non-sustainable" conditions will continue into the future, and even further decline, in the absence of the system investment plan and its implementation. Regarding RFFAs, it is anticipated that the sustainability of the transportation and traffic system will improve as a result of navigation investment actions identified in this report.

FIGURE 10-16
ES of Transportation and Traffic System



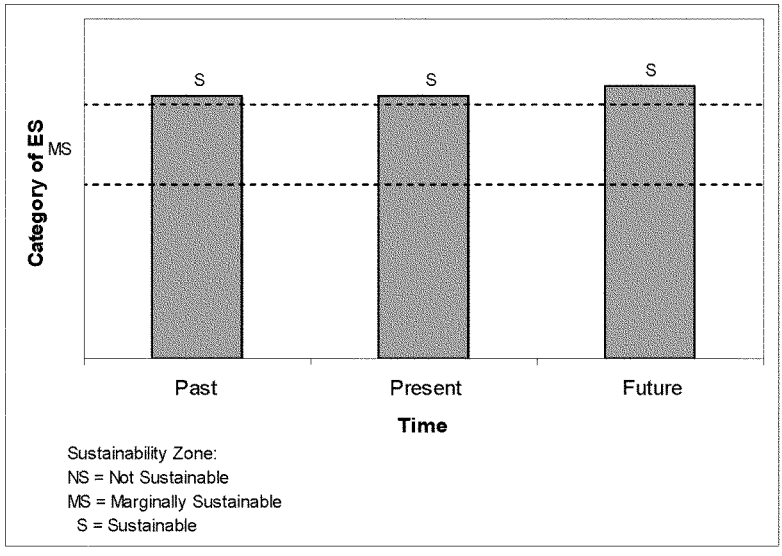
I. Socioeconomic Resources

1. Historic, present and future trends for socioeconomic resources in the Ohio River study area illustrate a pattern of increasing sustainability, related to population growth and conversion of natural resources and landscapes.

2. The past was characterized by rapid conversion of natural resources and landscapes to meet the industry and infrastructure demands of a rapidly expanding population. Although socioeconomic resources were generally sustainable, volatile patterns of explosive growth and recession cycles occurred such that the ES was somewhat less stable than in recent decades.

3. At present, the region offers a reasonably healthy mix of agriculture, varied industries, and commercial, financial, education, and health care services and is supported by a fully developed economic infrastructure. This economic infrastructure includes rail, highway, river and air transportation, modern communication capabilities, and affordable and reliable utilities, including coal fired electricity generation that depends directly on the river navigation system. The social system is equally well established, with a generally healthy, educated, and technically skilled population supported by an established network of urban, suburban, and rural communities.

Figure 10-17
ES of Socioeconomic Resources



4. In recent decades, improved water quality has contributed to increased redevelopment interest for many riverfront neighborhoods. Growing interest in environmental amenities within residential/commercial settings contributes to the design of community oriented restoration projects that combine floodplain functionality, aquatic and riparian habitat enhancement, open space, recreational activities, stormwater detention, and related functions within multi-purpose or integrated aquatic restoration projects.

5. Regarding RFFAs, the projected slow population growth and attendant slow growth of the economy allows for a gradual expansion from the existing infrastructure and an opportunity for relative economic stability in contrast to the 'boom and bust' patterns of the past century. The projected growth patterns may present opportunities to proceed with gradual and better planned processes of development and redevelopment serving the needs and interests of a stable and established population. This steady pattern for development should score higher for sustainability than the more volatile pattern of the past.

6. Further, ongoing investments in social and economic infrastructure should have a generally positive impact on socioeconomic resource values. For the Ohio River valley, most primary infrastructure investments have already been accomplished, including a complete system of interstate and other primary highway networks, railroads, river bridges, airports, locks and dams, levees and floodwalls. Expansion plans for infrastructure continue on the basis of projected demand or existing capacity expansion needs, but a relatively stable population for the foreseeable future should contribute to reduced demand for additional primary infrastructure. Future improvements to this system would focus primarily on maintenance, refinement, rehabilitation, improvement, or replacement of the existing inventory.

7. Lock extension/replacement, major rehabilitation, and ongoing maintenance/repair of existing locks would contribute to positive socioeconomics impacts for all segments of the population. Environmental Justice concerns were examined and it was determined that benefits would accrue to minority and low income populations in proportion to the overall population. Further, no minority or low income populations would be disproportionately impacted by system investments in navigation or environmental sustainability. Within the context of the larger economy of the Ohio River valley, these actions would contribute fairly small, but cumulative impacts. Long term growth of navigation traffic will require more tugs and barges in operation, more terminals and related port facilities, more maintenance dredging for expanded terminals, and expanded areas of fleeting operations. These expansions would convert existing floodplain lands (e.g., farmland, riparian woods, and wetlands) that now afford habitat protection, open space, and ecosystems values. Once converted, such lands are unlikely to revert to their former more natural states. Expansion of navigation infrastructure would also compete for space with expansion of riverfront industries, coal fired utilities, mining, and other commercial operations. Mixed-use urban waterfront developments, marinas, and other recreation-oriented developments would also compete for waterfront space. Waterfront development policies that support the conversion of brownfields, unused or underdeveloped terminals, or other underutilized industrial sites could help to minimize conversion impacts to existing agricultural uses or riparian habitats.

J. Cultural Resources

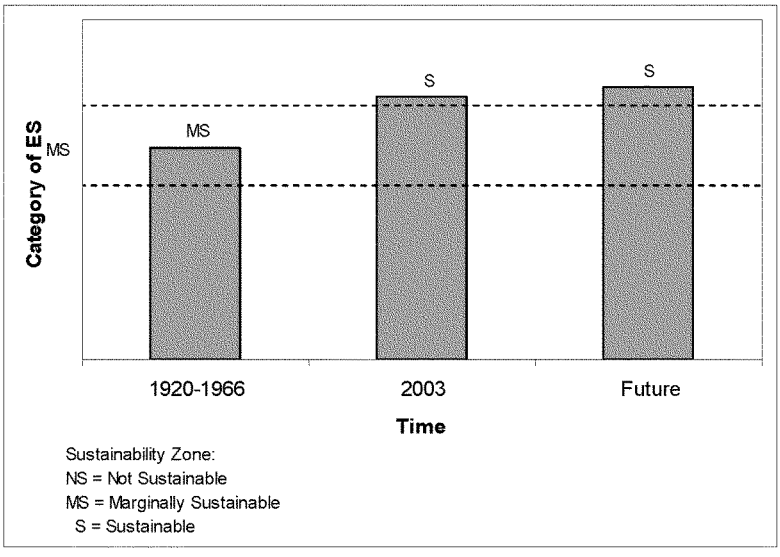
1. In the period from 1920 and continuing until passage of the National Historic Preservation Act of 1966 and other preservation acts later in the 20th century, limited measures were in place to preserve and protect cultural resources; most resources

remained unsurveyed. Widespread razing of potentially historic structures during this time is viewed by some State Historic Preservation Office (SHPO) professionals as having contributed to a decline such that cultural resources may overall have been at the "marginally sustainable" level.

2. The implementation of cultural resources legislation, including creation of the National Register of Historic Places (NRHP) and establishment of SHPOs, has heightened awareness of the need to preserve historic structures in communities along the Ohio River. Simultaneously, National Historic Preservation Act provisions that require consideration of cultural resources where federal involvement occurs have led to the discovery and preservation of previously unknown cultural resources. Accordingly, the ES classification for the current time is "sustainable."

3. Regarding RFFAs, federal and state regulations concerning cultural resources are expected to remain in place and help maintain a "sustainable" condition. The Corps has executed Memoranda of Agreements with all six SHPO offices that will direct cultural resource compliance for all work recommended in this report (See **Environmental Appendix**). Also, during each year of this study, additional resources have become eligible for possible placement on the NRHP, although some SHPO professionals have observed that numbers of NRHP candidate properties may be limited due to societal trends toward disposability, tear down, and sprawl. Additional riverfront development, including recreational areas may result in covering or damage to cultural resources near the land surface.

Figure 10-18
ES of Cultural Resources



Positive trends related to cultural resources include:

- the development of predictive models to determine probability for cultural resources occurrences.
- recent emphasis on context integration of historic districts.
- an increasing number of river festivals and other events through which residents of the Ohio River valley are rediscovering the rich cultural heritage of the river.

10.2.2.3. Interactions With Other Valued Environmental Components

1. Cumulative effects assessment not only considers past, present, and future conditions and trends for individual VECs, but also the interactions which may occur among VECs. Assessment of VEC interactions is prescribed in Step 8 of the CEQ Guidelines: Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.

2. VEC interactions for the Ohio River mainstem were visualized by constructing a crosswalk of all potential interactions which were then ranked as high, medium, or low/no interactions, as shown in **Table 10-32.** Interactions rankings were based on information presented in individual VEC chapters of the CEA, as well as on best professional judgment of the project team members.

TABLE 10-32
Interactions Among VECS in the ORMSS CEA

VEC Interactions*	WQ & SQ	Fish	Mussels	Riparian/Floodplain Resources	Air	Health & Safety	Recreation	Transportation	Socioeconomics
Cultural Resources									
Socioeconomics									
Transportation									
Recreation									
Health & Safety									
Air									
Riparian/Floodplain Resources									
Mussels									
Fish									

*Key to shading:

High

Medium

Low or no interaction

10.2.2.4. ES OVERVIEW OF ALL VECS

1. Of 45 VEC interactions cross-referenced in the **Table 10-32**, 23 display a high level of interaction, 14 display medium interaction, and 8 potential interactions either have no or low interaction. The four VECS with the highest interaction levels are water & sediment quality (6 highs), recreation (7 highs), transportation (6 highs), and socioeconomics (6 highs). Other important VECs have fewer interactions in part because they are confined to only one environmental medium. Fish and mussels, for example, are confined to water and, accordingly, have very limited interaction with VECs such as air and cultural resources.

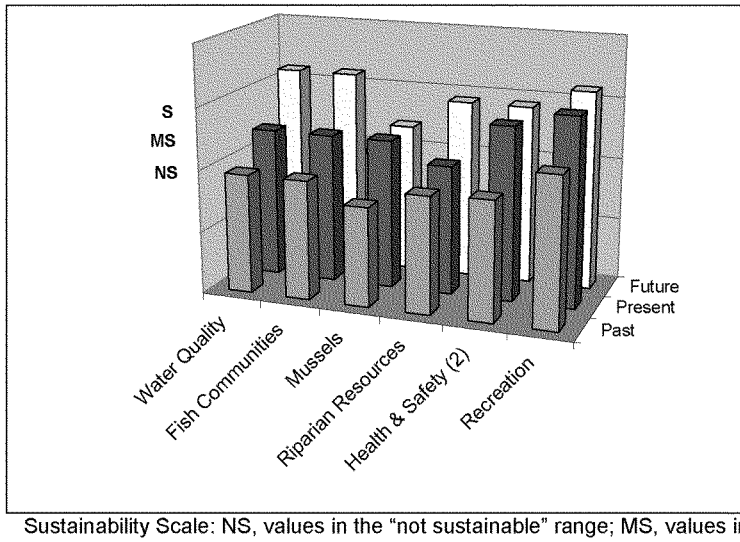
2. Combining ES classifications for individual VECs with interactions among VECs reveals an overview for all ten VECS discussed in the ORMSS CEA. In this context, ES values of certain VECs become important "drivers" that influence ES values

of other VECs in the overall system. Most notably, dramatic improvements in ES of the Water Quality VEC, subsequent to implementation of ORSANCO programs and the Clean Water Act, have driven the other components of the aquatic ecosystem of the Ohio River toward increased ES. The ES of fish has measurably improved, while ES of riparian resources and mussels have benefited to a lesser extent. Cleaner water and improved aquatic resources in turn have enhanced recreational boating and fishing on the mainstem and stimulated growth of related support facilities such as marinas. Cleaner water nationwide also has contributed to a trend toward increased development and use of trails, greenways and other recreational facilities along rivers, including the Ohio mainstem. Such recreation facilities often stimulate riverfront development, including restaurants and entertainment districts, which add to local economic growth, but concomitantly contribute to loss of riparian/floodplain resources and cultural resources.

3. Health & Safety represents a VEC with improved ES in recent decades (due to improved water quality and more stringent workplace regulations), but with the potential for its ES to be driven downward by complex interactions with other VECs. Possible growth of commercial navigation, recreational activity, river-oriented industries, and other river users will require vigilance in management and regulation of H&S issues just to maintain the status quo.

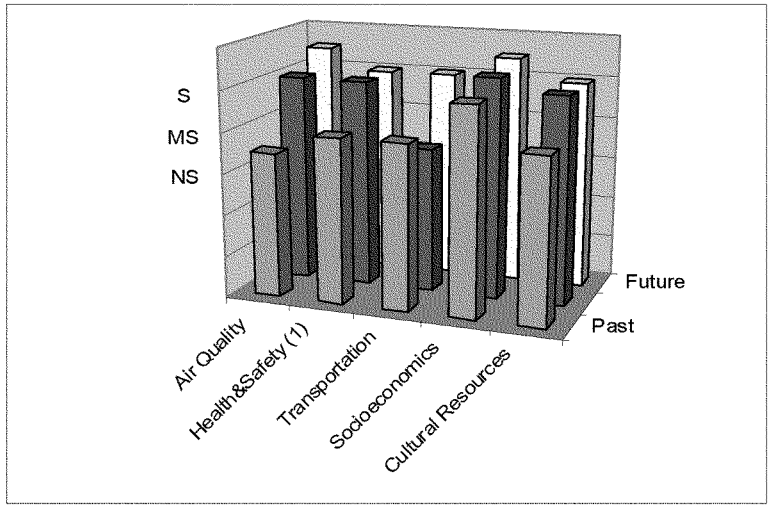
4. ES values of riparian/floodplain resources (RFR) and mussels are particularly confounding in part because of somewhat limited knowledge of these VECs. Regarding RFR, lack of knowledge until recently was correlated with the relatively low value assigned to these resources. Although interest in RFR has increased, these resources present a challenging complex of biogeochemical, hydrological, and ecological processes. Similarly, Ohio River mussels are challenging to study, despite the fact that information on Ohio River mussels has been collected since the 1800s. Scientists studying mussels are hampered not only by lack of knowledge of reproductive cycles and habitats needs, but also by increased water depths due to impoundment of the river and the lack of systematic monitoring of mussel resources. **Figures 10-19 and 10-20** depict past, present and future ES levels for all VECs.

FIGURE 10-19
ES Trends for VEC Group 1



Sustainability Scale: NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range

FIGURE 10-20
ES Trends for VEC Group 2



Sustainability Scale: NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range

10.2.3 Discussion of Direct and Secondary Influences

10.2.3.1 Eroded Savings

1. As noted in **Section 8** (WOPC) and earlier in this section (WPC), an economic metric, that also infers environmental consequences, is "eroded savings". This metric refers to reductions in system economic benefits resulting from unscheduled repairs at existing locks. Such repairs are expected to result in more queuing of on-river navigation traffic in the immediate downstream areas of locks subjected to such repairs. Navigation-related consequences of unscheduled repairs include increases in the number of transit days associated with the movement of goods within and through the system, and general reductions in the efficiency of the system. Environmental-related consequences of unscheduled repairs include local habitat reductions from queuing in the immediate downstream areas, and general environmental disruptions due to the specific activities associated with the repairs. The extent of queuing as well as the associated environmental consequences will be a function of the types and complexities of the unscheduled repairs.

2. **Table 10-33** summarizes the eroded savings metrics as contained in **Tables 8-8** (RMA), **10-6** (AMA), **10-9** (MRA), and **10-12** (LMA). These metrics are in millions of FY03 dollars, at a 5 1/8% discount rate, expressed on an average basis over the 2010-2070 study period. The data are displayed for each of the four navigation-related plans and each of the five navigation traffic scenarios. The table also includes summary information on unscheduled lock repair costs over the same study period. The following comments are relevant to the eroded savings data summarized in **Table 10.33**:

- For each of the traffic scenarios, the eroded savings decline as a function of the comprehensiveness of the navigation-related plan. For example, the least comprehensive plan (WOPC-RMA) has the highest eroded savings for each scenario, as well as the highest cost for unscheduled lock repairs. In contrast, the most comprehensive plan (WPC-LMA) includes all the measures in the RMA, AMA, and MRA alternatives. Thus, for every scenario, the LMA yields the lowest eroded savings and lowest cost for unscheduled lock repairs. Further, in relation to the other plans, the LMA minimizes the negative environmental effects of queuing and the activities related to unscheduled repairs.

- For each navigation-related plan, the eroded savings increase as a function of the traffic scenario. The scenarios are listed by increasing navigation traffic; e.g., the lowest traffic is for the Clear Skies scenario, while the highest traffic is for the Utility-Based High scenario. In general, the lowest cost for unscheduled repairs is associated with the Clear Skies scenario, while the highest is for one or more of the other scenarios.

- If eroded savings were the only factor to consider in identifying the "best" navigation-related plan, the LMA could be clearly identified as this best system investment plan.

TABLE 10-33
Summary of Eroded Savings and Direct Costs Resulting from Unscheduled Repairs[a]

Traffic Scenario	Navigation-Related Plan			
	WOPC (RMA)	WPC (AMA)	WPA (RMA)	WPC (LMA)
Clear Skies	75.8 (14.0)	17.6 (4.3)	17.6 (4.2)	12.9 (4.0)
Modified Clear Skies	119.8 (15.1)	74.4 (8.4)	62.7 (7.4)	20.7 (4.3)
NAAQS Growth	124.1 (15.0)	37.1 (5.0)	36.9 (4.8)	19.4 (4.2)
Utility Based	107.7 (14.7)	56.3 (7.6)	56.1 (7.3)	20.8 (4.2)
Utility Based High	120.3 (15.0)	61.2 (7.7)	61.5 (7.3)	23.6 (4.2)

[a] for each plan and scenario, the first number is eroded savings, the number in parenthesis is the cost for unscheduled lock repairs (average annual basis, 2010-2070, 5 1/8%, Million FY03 $)

10.2.3.2 Transit Time

1. A metric that can be used to reflect the efficiency of the navigation system relative to the movement of goods is average transit time expressed in days. **Figure 10-7** (see **Section 10.1.5.4**) displays transit days within the system versus the study time period from 2010 to 2070, averaged over all five traffic scenarios. The displayed transit days are the total days that all tows are expected to spend in transit on the river in a given year. These days are associated with the total annual tonnage on the river (**Figure 10-6**) and the associated equilibrium traffic relative to numbers of tows. The term "equilibrium traffic" reflects all the traffic that is moving on the system with a positive rate savings given the physical and hydrodynamics conditions. For a given time period (year), the physical conditions can be altered by conducting routine maintenance, advanced maintenance, major rehabilitation, and/or lock modernization projects at various locks within the system. When such projects require lock closures, they would tend to cause more queuing and thus increase annual transit days while they are occurring. Further, annual transit days could be influenced by naturally occurring hydrodynamic conditions (e.g., flooding). Flooding conditions would cause disruptions in routine lock operations, and thus local queuing in lock approach zones would be expected.

2. The top curve in **Figure 10-7** reflects the WOPC (RMA) navigation plan averaged over the five traffic scenarios. The overall increase over the study period is primarily reflective of both the increased tonnage moved on the river (**Figure 10-6**) and a greater number of reactive maintenance activities at all the locks on the system. The zigzag nature of the WOPC plan is indicative of both scheduled closures as well as unscheduled repair activities.

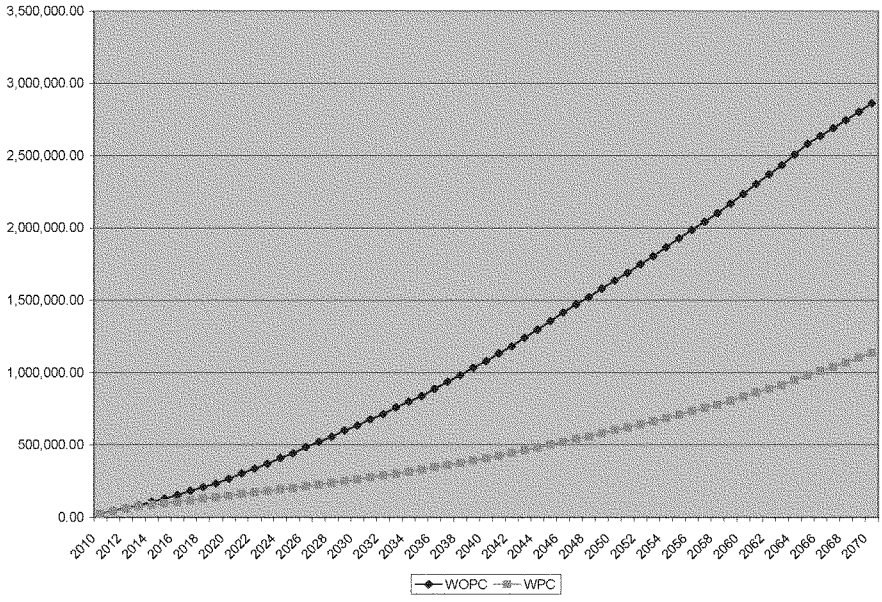
3. The bottom curve in **Figure 10-7** represents the most comprehensive of the WPC plans; namely, the LMA plan averaged over the five traffic scenarios. Further, it should be noted that this plan includes the measures from the RMA, advanced maintenance measures from the AMA, major rehabilitation projects from the MRA, and the lock extensions at EDM from the LMA. As can be seen, the annual cumulative system transit days for the WPC are considerably less than for the WOPC from about 2013 through 2070. The divergence in the WOPC and WPC data in 2013 is based on assumptions that the lock projects at EDM will be completed along with major rehabilitation projects at the Markland, Hannibal, Meldahl, and Myers locks. Because the scheduled improvement projects associated with the WPC increase reliability and, therefore, reduce closure, the zigzag pattern of the WOPC is not present.

4. The differences in the WOPC and WPC curves in **Figure 10-7** indicate that the WPC plan (LMA) will yield both a more efficient navigation system, as well as a system subject to lesser queuing and thus reduced negative effects in lock approach zones. In fact, the differences in annual cumulative transit days are not uniformly dispersed across the system; rather, they are exclusively due to queuing in the approach zones above and below the current lock and dam projects. Finally, the differences in annual system transit days range from about 15,500 in the 2015 to 2020 time period, to about 33,500 in the 2030 to 2070 time period.

5. **Figure 10-21** displays the year-to-year cumulative transit days for the WOPC (RMA) plan and the WPC (LMA) plan averaged over all five traffic scenarios. By progressively cumulating the annual system transit days across the study period, the zigzag pattern for the WOPC (RMA) plan, as shown in **Figure 10-7**, is essentially eliminated. As **Figure 10-21** illustrates, the differences in the WOPC and WPC cumulative transit days are about 116,000 by 2020; 372,000 by 2030; 671,000 by 2040; 1,034,000 by 2050; 1,400,000 by 2060; and 1,725,000 by 2070.

6. Accordingly, the progressive increase in transit days clearly illustrates important benefits of the WPC (LMA) plan relative to improvements in system navigation efficiency and reductions in queuing in important habitat areas in the approach zones of individual lock projects.

FIGURE 10-21
Cumulative Transit Days – WOPC vs. WPC

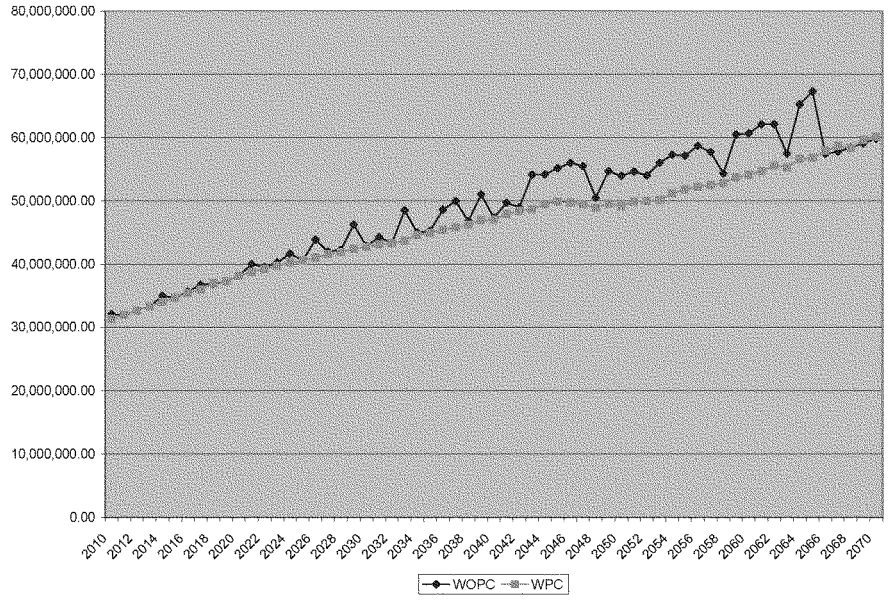


10.2.3.3 Diverted Traffic

1. An additional metric that can be used to reflect the efficiency of the navigation system relative to the movement of goods is illustrated by the concept of diverted traffic. This concept addresses freight that might have been moved on the Ohio River, but is diverted to rail or highway transportation. Calculations of diverted traffic over the study time period from 2010 to 2070 and averaged for all five traffic scenarios are presented in **Figure 10-22.**

2. **Figure 10-22** indicates that similar rates of diversion are estimated for both the WOPC and the WPC. Over the 60 year span of the study period, diverted tonnage under WOPC represents 15.35% of all traffic moved, while the WPC results in 14.41%. The improvements under WPC are attributable to greater transportation efficiencies that result from proactive maintenance, major rehabilitations, and new lock chambers at EDM. The cumulative benefit for the study period totals about 160 million tons of freight not diverted due to improved WPC efficiencies. This represents an annual average of 2.67 million tons, although as indicated in the figure, the model predicts diversions to occur as concentrated events reflecting intermittent periods of congestion and delay under the WOPC. Diverted tonnage attributed to WOPC represents about 5.4% of all diverted traffic or about 0.8% of total traffic moved on the river.

FIGURE 10-22
Tonnage Diverted from Ohio River



3. The environmental impacts of diverted traffic can be talked about in two contexts. One context focuses on impacts of moving the diverted freight by rail and highway modes. The other context looks at impacts to Ohio River VECs associated with traffic leaving the river.

4. With respect to traffic diverted to alternative modes, quantitative impacts would occur with increased fuel consumption, air emissions, deterioration of roads, increases in traffic-related injury, and corresponding increases in the delivery price of diverted materials. The cyclical nature of diverted traffic may contribute to temporary increases in highway congestion or slight delays in deliveries by rail. Since the WOPC predicts that reactive repairs will eventually restore functionality to the river transportation system, it seems unlikely that infrastructure expansions would occur in the rail or highway systems. However, electric utilities and other customers of river traffic may implement marginal expansions of storage yard capacities to compensate for periodic delivery disruptions.

5. Impacts to Ohio River VECs could include reduced impacts to aquatic and riparian resources attributable to reduced levels of construction induced queuing. Reduced air emissions and improved safety conditions in the lock approach areas would also result. Due to the cyclical nature of such diversions, permanent improvements to environmental sustainability factors would not be expected.

10.2.3.4 Construction Impacts Of WPC Alternatives

All WOPC and WPC alternatives will have some degree of construction impacts, including repairs that necessitate closure of main chambers and generate queuing impacts. On a comparative basis, all four alternatives are similar with respect to cyclical, reactive and/or advanced maintenance impacts. Two alternatives under the WPC additionally involve extensive construction activities that would have impacts on terrestrial and aquatic habitats. These alternatives are major lock rehabilitation (MRA) and lock modernization (LMA).

Impacts of Major Lock Rehabilitation

Major rehabilitations of locks would be projected to continue for about four years with the following anticipated impacts:

- Alteration of approximately 10 acres of terrestrial habitat to be used as a lay-down area during the rehabilitation. Clearing of vegetation will be required to prepare the lay-down area consisting of two esplanades, each approximately 150' by 1400' long. The actual size of the work area may vary somewhat based on the amount of land within a contractor's work limits, as well as the amount of government owned land available at the site.

- Approximately 1 acre of the above 10-acre site would permanently be impacted by the building of a construction office and assembly piers and the possible storage of materials removed during the rehabilitation. The remaining acreage not permanently affected could require decades to return to pre-disturbance conditions, unless revegetation to achieve a desired outcome is promptly implemented.

- Assuming the contractor needs an area to load and unload materials onto barges and to float in materials, approximately 400 ft. of bank would be disturbed during the four-year process.

- Dewatering of 600' x 110" lock chambers would affect approximately 3 acres of aquatic habitat for 5 months while dewatering of 1200' x 110' lock chambers would affect approximately 5 acres of aquatic habitat for 5 months.

Impacts of Lock Modernization

Lock modernization would last longer (up to 7 years) and involve larger impact areas than MRA, with impacts varying by site depending upon the quality and quantity of terrestrial and aquatic habitats present. The following discussion focuses on impacts anticipated during lock construction at Emsworth, Dashields and Montgomery (EDM) Locks in the upper Ohio River. Modernization of each of these three locks would involve creation of a new 600' x110' chamber where a 56' x 360' chamber presently exists.

Impacts of the EDM modernizations would be as follows:

- Terrestrial impacts could occur within a 100-acre work area. Although impacts may temporarily occur throughout the work area, approximately 11 acres would be directly affected temporarily for a lay-down area, batch plant, and material stockpiles. Another 20 acres would be expected to be permanently altered to serve as an excavation spoils area. Although such an area would be permanently affected, it could be revegetated to eventually restore terrestrial habitat.

- Approximately 100 linear feet of riverbank would be disturbed at each of the EDM sites. To remediate the site upon project completion, the bank may be riprapped beyond its present extent.

- The structural footprint of each new modernized lock, including the guide walls and fill, would permanently impact 2 1/2 acres of aquatic habitat – a net increase of about 1 acre from the 360' x 56' chamber. The 1 acre represents aquatic habitat lost because the area may be paved or cleaned to bedrock and will be subject to boat traffic, dredging, and constant fill and empty cycles.

- New locks will create 2 ½ acres of embayment area at each site. Aquatic habitat in these areas, between the guard wall and the riverbank, will be permanently impacted by altered flow, concentrated boat traffic, and regular dredging.

- During lock construction, a 4 to 4 ½ acre area is expected to be temporarily dewatered at each site, effectively removing the area as aquatic habitat during that time.

Lock Closures

Both major rehabilitation and lock modernization projects would require some degree of main chamber closure during the construction period. The total length of closure is a very site specific variable. A number of measures are employed to minimize the economic and environmental impacts of such closures. Before construction begins, the auxiliary chamber is inspected and repaired as necessary to ensure reliable operability for the duration of the construction effort. To the extent feasible, shorter closures are distributed throughout the construction period to avoid overlong or too frequent closures. Detailed estimates of the length and timing of such closures are developed during the site-specific feasibility studies. The schedule of closures is published and distributed to the transportation industry well ahead of time to facilitate planning on their part. Impacts associated with these closures would be more specifically addressed in site specific feasibility studies.

10.2.3.5 Expansion of Terminals and Fleeting Areas

10.2.3.5.1 Impacts of Intermodal Facilities

1. Intermodal facilities provide linkages between water and rail or ground transportation that extends commerce on the Ohio River far beyond the Ohio River Basin. The Corps' Inland Navigation Center surveyed intermodal facilities within the region to determine if any facilities would require expansion under various scenarios that could affect terrestrial or aquatic habitats.

2. Only one major facility responded to the survey; therefore, potential future impacts need to be interpolated from these data. Intermodal facilities would distribute large quantities of Powder River Basin coal to utility plants along the Ohio River if western coal is used in the future. Response to the Inland Navigation Center's survey indicates that during the ORMSS planning period additional ground capacity (in acres) for coal storage and additional fleeting area (in acres) capacity may be required. As **Tables 10-34 and 10-35** indicate, the amounts of additional storage and fleeting capacities vary by year and traffic scenario. The NAAQS scenario is predicted to require the largest cumulative increase in storage and fleeting capacities, while the Clear Skies scenario is predicted to require the smallest increase.

Table 10-34

Needed Additional Ground Capacity (Acres) from Current (2005) at One Facility					
Year	Utility-Based High	Utility-Based	NAAQS	Clear Skies	Modified Clear Skies
2010 0		0	10	0	10
2015 4		1	20	0	17
2020 7		4	27	5	24
2025 12		7	26	5	21
2030 16		10	28	5	23
2035 19		12	31	5	26
2040 24		15	35	5	29
2045 28		18	38	5	32
2050 26		16	38	5	32
2055 31		18	42	5	35
2060 36		21	45	5	38
Note:	Quantities were calculated assuming current use of 29 acres for ground storage.				

Table 10-35

Needed Additional Fleeting Capacity from Current (2005) at One Facility					
Year	Utility-Based High	Utility-Based	NAAQS	Clear Skies	Modified Clear Skies
2010	0	0 14		0	15
2015	6	2 30		0	26
2020	11	6 41		8	36
2025	18	11 39		8	32
2030	24	14 42		8	35
2035	29	18 47		8	39
2040	36	22 52		8	44
2045	42	26 57		8	49
2050	40	24 57		8	49
2055	46	28 62		8	53
2060	53	31 67		8	58
	Note:	Quantities were calculated assuming current use of 30 acres for fleeting area.			

3. The current Terminal ground storage capacity for coal is constrained, with expanded ground capacity needed now. **Table 10-35** also shows the need for additional fleeting capacity soon. Expansion of ground capacity would functionally remove any terrestrial habitat in the area affected. Expansion of fleeting areas would impair aquatic habitat with impacts varying relative to pre-existing habitat quality.

4. It is important to note the speculative nature of reporting the predictions of only one industrial facility. Growth projections based solely on that facility's mix of commodity shipping services are limited to a fairly short time horizon (approximately 20 years).

5. The survey also noted the presence of 2 or 3 additional multi-modal ports within the navigation systems whose operations would be influenced by freight demands on the Ohio River. As mentioned above, these ports did not respond to the survey.

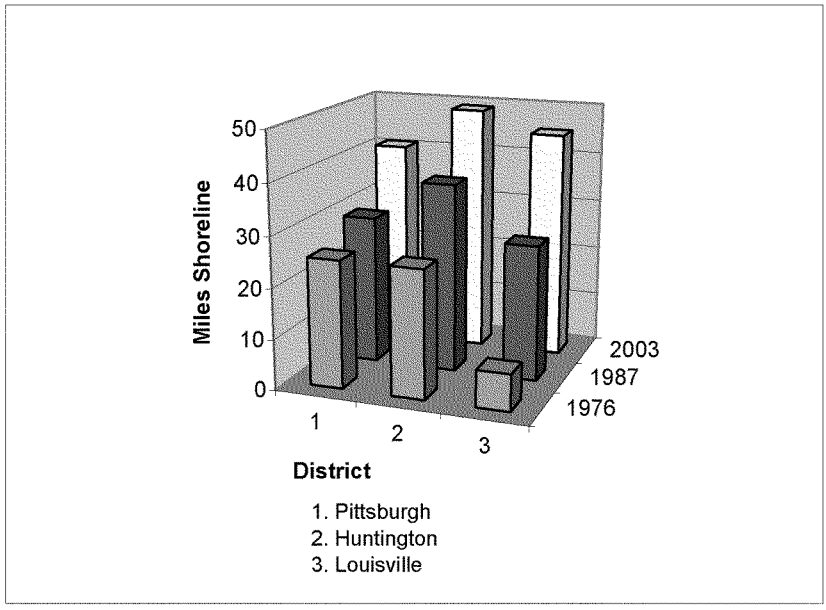
10.2.3.5.2 Fleeting Areas and Competing Uses of Ohio River Resources

1. Efforts to characterize historic trends on the Ohio River were carried out as part of the CEA and are summarized in the following section. By correlating past fleeting/terminals data with historic traffic, one can project future demand for fleeting/terminal space based on traffic projections.

2. The CEA study also considered the use of Corps issued permits (Sections 10 and 404) to track growth, distribution, and cumulative impacts of terminals and fleeting areas. Unfortunately, long term records of issued permits are not maintained, preventing use of this approach to establish historic trends. In the future, appropriate data from permits could be assimilated in a central database for all inland navigation activities. This would greatly improve the Corps' ability to monitor the cumulative impacts of navigation.

3. In addition to the size and number of barges and towboats on the river, the industry requires space for terminals and fleeting activities. Barge and tow activity is reflected in records of net tonnage of commerce shipped on the river (see Section 4). These records provide a detailed history of the growth and distribution of commercial navigation, and an indirect indicator of the growth of shipping infrastructure needed to sustain commercial expansion. Areas devoted to fleeting and terminal activity can also be calculated from Ohio River Navigation Charts. These records are displayed in **Figure 10-23**.

FIGURE 10-23
Mapped Fleeting Areas on the Ohio River



Source: U.S. Army Corps of Engineers, Navigation Charts

4. For the total river, areas devoted to fleeting have increased by 233 per cent from 1976 to 2003. As of 2003, 135 miles of shoreline were used for fleeting activities,

representing 6.9% of the Ohio River's total shoreline (981 miles x 2). The rate of increase has been steepest on the lower half of the river; fleeting areas have increased by over 600% in the Louisville District. Shoreline mileage utilized for fleeting activities on the Ohio River is summarized below in **Table 10-36.** It should also be noted that if expansion of these facilities become cost prohibitive in the future, the infrastructure currently in place is probably adequate to handle most future demand through increased efficiencies.

TABLE 10-36
Miles of Fleeting Activity on the Ohio River

Year	Pittsburgh District	Huntington District	Louisville District	Total
1976	25.3	25.3	7.3	57.9
1987	29.4	37.4	26.8	93.6
2003	40.7	49.1	45.1	134.9

Source: U.S. Army Corps of Engineers Navigation Charts

10.2.3.6 SUMMARY OF NAVPAT ANALYSES

1. The Corps has conducted substantial research on the potential for commercial tows to disturb bottom substrates and interfere with fish reproduction, recruitment, and feeding. To address these potential incremental biological effects of various navigation planning scenarios, more than 20 years ago the Louisville District developed the Navigation Predictive Analysis Technique (NAVPAT). Since its inception, many refinements have been made to the NAVPAT model in efforts to yield the most useful and accurate information. The 2005 version of NAVPAT was used in the ORMSS. Details related to the NAVPAT study and findings are in the **Environmental Appendix** under the title "NAVPAT Application to the Ohio River Mainstem Systems Study and the Evaluation of NAVPAT Relationships".

2. The goal of NAVPAT is to provide quantitative results, which can be used to assess positive or negative effects of tow movement on available aquatic habitat quality for a river reach or a specific area of a river cross-section (called a "cell"). Although NAVPAT focuses on certain fish species and their life stages, NAVPAT does not provide specifics on the response of any particular species. Instead NAVPAT generally links tow movements to possible habitat effects. The habitat relationships in NAVPAT were developed by an interdisciplinary team, comprised primarily of biologists from the US Fish & Wildlife Service (USFWS) and state natural resource agencies. NAVPAT outputs provide quantitative values of projected environmental effects of various navigation proposals at one or more time intervals in units that are habitat-based and essentially "habitat units".

10.2.3.6.1 Input Considerations

1. **Table 10-37** presents the fish life stages used in the ORMSS study, the identifying number each stage is assigned in NAVPAT, the rationale for species selection, and the potential impacts of concern.

TABLE 10-37
Fish Life Stages Selected for Ohio River NAVPAT Model

Fish Species	Life Stages of Concern (NAVPAT number)	Rationale for Species Selection	Potential Impacts of Concern
Emerald Shiner	Spawning (1) ES(s) Fry (2) ES(f)	Represents open water spawners in areas of lower ambient current velocity and fry with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of non-adhesive eggs as water velocity increases with tow passage 2) Destruction of fry caused by entrainment through propellers or associated pressure and turbulence
Paddlefish	Spawning (3) P(s) Larval stage (4) P(l)	Represents open water spawners in areas of moderate ambient current velocity and fry with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of adhesive eggs as water velocity increases with tow passage 2) Destruction of fry caused by entrainment through propellers or associated pressure and turbulence
Freshwater Drum	Egg/larval stages (6) FD(l)	Represents open water spawners in almost any portion of a river and adults that feed on organisms found in bottom sediments	1) Destruction of egg/larval stages caused by entrainment through propellers or associated pressure and turbulence 2) Dislodgment of substrates caused by water velocity from tow passage
Sauger	Spawning (7) S(s) Larval stage (8) S(l)	Represent spawners in relatively high ambient current in areas with coarse substrate and larvae that move to areas of lower ambient current velocity with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of adhesive eggs as water velocity increases with tow passage and/or abrasion of eggs due to substrate scouring 2) Destruction of larvae caused by entrainment through propellers or associated pressure and turbulence
Spotted Bass	Spawning (14) SB(s)	Represents nest spawners in moderate depth water with coarse substrates and juveniles that feed significantly on small	1) Dislodgment of eggs from nests because of water velocity increases with tow passage and vulnerability of eggs to predation 2) Disturbance of substrate

		benthic invertebrates	that could reduce the availability of aquatic insects on which these fish feed
SOURCE: U.S. Army Corps of Engineers, Environmental Effects of Commercial Navigation Traffic – McAlpine Lock and Dam Project, NAVPAT and QUEPAT (not dated).			

2. The NAVPAT traffic scenarios were based on five detailed lock-level traffic demand forecasts the Corps has developed for the Ohio River. These scenarios include potential impacts of concern. The developed habitat relationships for each species/life stage were inputs to the NAVPAT study. The three other primary NAVPAT inputs were:

- river reach characteristics – including information describing multiple reaches of a river which share basic aquatic habitat conditions; i.e., reaches with similar bathymetry, substrate, depth, and velocity profiles

- economic scenarios – including data on various navigation forecasts, as well as data simulating various tows by length, width, speed, travel direction, horsepower, propeller dimensions, and other measurable characteristics, and utility coal forecasts that reflect the effects of coal source switching by electric utilities to comply with existing or proposed environmental regulations.

- physical forces – including information about several types of hydraulic forces generated by tows moving through a waterway. NAVPAT is best used in primary navigation channels as flows in side channels are significantly more complex and not within the scope of the present model.

3. The actual input files for the NAVPAT model included river cross-section data files, river tow traffic files corresponding to the given traffic scenarios, tow position frequency files, and river stage and discharge data files. Section IV of the above-mentioned NAVPAT appendix describes the specific methods used for collection of substrate, bathymetry, and shoreline structure data. Further, detailed information is included on the creation of bathymetry/cell files, traffic files, sailing lines and tow positions, and stage and discharge files.

10.2.3.6.2 Output Features

The habitat relationships for the five species and eight life stages listed in **Table 10-37** yield a qualitative index of the "suitability" of each cell for providing the needed habitat for the species/life stages. These HSIs (habitat suitability indices) range from 0 (no quality) to 1 (optimum quality). When the cell's HSI for a species/life stage is multiplied by the area of the cell (in acres), the product is termed Habitat Units (HUs). Accordingly, HUs can be considered as acres of habitat of some level of suitability for the species/life stage. Such HUs have been displayed by species/life stages for pools upstream of each of the 20 current locks and dams, for three river reaches (upper, middle, and lower), and for the entire Ohio River mainstem.

10.2.3.6.3 Discussion of Results

1. The composited river reach HUs for the five species and eight life stages are displayed in **Figure 10-24** and **Table 10-38**. The displayed HUs are for the navigation traffic associated with the Without Project Conditions (WOPC) in 2010. The WOPC, also known as the Reactive Maintenance Alternative (RMA), is described in Section 8. Accordingly, the WOPC in 2010 reflects the "baseline condition" for comparing the HUs for future WOPC and With Project Conditions (WPC). The WPC is described in Section 9. The Upper River segment extends from the Emsworth pool at RM 0 to the Greenup Lock and Dam at RM 341. The Middle River segment continues from the Greenup Lock and Dam to the McAlpine Lock and Dam at RM 607. The Lower River segment extends from RM 607 to the confluence with the Mississippi River at RM 981. The following observations can be made in relation to **Figure 10-24**:

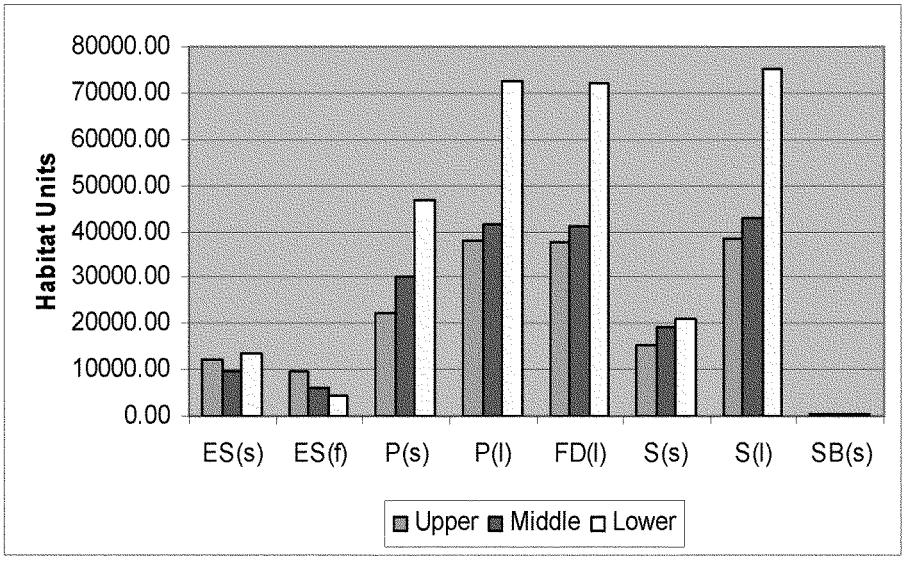
- The HUs for Paddlefish-Larval, Freshwater Drum-Larval, and Sauger-Larval demonstrate similar levels (about 38,000 to 42,000) for the Upper and Middle segments, as well as similar levels (about 72,000 to 75,000) for the Lower segment. Although at different HU levels, these patterns are also seen for Paddlefish-Spawning and Sauger-Spawning.

- The HUs for Emerald Shiner-Spawning are at similar levels (about 10,000 to 13,000) for all three segments. For Emerald Shiner-Fry, the HUs decrease from the Upper segment (about 10,000 HUs) to the Lower segment (about 4,000 HUs).

- The HUs for Spotted Bass-Spawning are considerably less than 1000 for all three segments (about 560, 290, and 290 for the Upper, Middle, And Lower segments, respectively).

- In general, **Figure 10-24** illustrates that HUs vary relative to both species and life stages for individual species. Further, the HUs increase from the Upper to Middle to Lower segments of the River. One possible explanation is related to the more narrow width and higher water velocities in the Upper segment in comparison to the other two segments.

FIGURE 10-24
Distribution of Without Project Habitat



See Table 10-37 for definition of species/life stages.

TABLE 10-38
Total HUs for Ohio River Mainstem (2010, WOPC, eight species/life stages)

Fish Species/ Life Stage	HUs			Total HUs
	Upper	Middle	Lower	
ES(s)	12,144	9,424	13,728	35,296
Emerald Shiner (spawning)				
ES(f)	9,624	5,877	4,255	19,756
Emerald Shiner (fry)				
P(s)	22,323	30,322	46,882	99,527
Paddlefish (spawning)				
P(l)	38,637	40,863	72,384	151,884
Paddlefish (larval)				
FD(l)	38,287	40,892	72,280	151,459
Freshwater Drum (larval)				
S(s)	15,330	19,164	21,089	55,583
Sauger (spawning)				
S(l)	39,099	42,399	75,312	156,810
Sauger (larval)				
SB(s)	559	289	291	1,139
Spotted Bass (spawning)				

- The HUs for Emerald Shiner-Spawning are at similar levels (about 10,000 to 13,000) for all three segments. For Emerald Shiner-Fry, the HUs decrease from the Upper segment (about 10,000 HUs) to the Lower segment (about 4,000 HUs).

- The HUs for Spotted Bass-Spawning are considerably less than 1000 for all three segments (about 560, 290, and 290 for the Upper, Middle, And Lower segments, respectively).

- In general, **Figure 10-24** illustrates that HUs vary relative to both species and life stages for individual species. Further, the HUs increase from the Upper to Middle to Lower segments of the River. One possible explanation is related to the more narrow width and higher water velocities in the Upper segment in comparison to the other two segments.

- Finally, it should be noted that the HUs in **Figure 10-24** are not reflective of the pre-navigation conditions of the Ohio River. Rather, they represent a river navigation condition at a point in time (2010). Nevertheless, these conditions can be used as "benchmarks" to examine the differences in HUs of WOPC and WPC at common points in time, and the differences of each condition over time.

2. As mentioned earlier, the focus of the NAVPAT study was the differences in HUs between the WOPC and the WPC. Such differences can be reflected in both HUs (delta) and the percentage change from the WOPC HUs (% delta). **Tables 10-39** through **10-41** contain the consolidated results for the Upper, Middle, and Lower river segments

under the five traffic scenarios and three selected years (2010, 2040, and 2070). The included results for the species/life stages are composites of the findings for all the pools in the respective segments. Detailed tabular and graphical information for each pool is contained in the above-mentioned Environmental Appendix.

3. To provide a basis for the examination of the delta values in **Tables 10-39** through **10-41**, the values can be considered in relation to the "2010- WOPC" total HUs for the individual species/life stage for all three reaches. These totals are summarized in **Table 10-38**; and they are also shown in **Figure 10-24**. The % delta numbers can be considered in two groups – those indicating less than a 3% change, either negative or positive; and those indicating a 3% or greater change.

4. The 3% threshold was selected based on a 2005 NAVPAT study of the Winfield Pool on the Kanawha River, and on the professional experience of Engineer Research and Development Center (ERDC) scientists and ORMSS biologists familiar with both the species habitat models and the assumptions and uncertainties associated with NAVPAT. Essentially, changes less than 3% are considered to be within the "statistical noise and variability" of the model results; thus, based on the current NAVPAT model, the forecasted changes do not represent actual anticipated changes that would be of concern. In contrast, changes of 3% or greater can be indicative of potential changes that should be considered in current decision making.

TABLE 10-39
NAVPAT Traffic Impacts Upper Ohio River

Fish Species/ Life Stage[1]	Traffic Forecast Scenario	2010				2040				2070				2010-2070			2010-2070		
		Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project 2010	Without Project 2070	% Delta	With Project 2010	With Project 2070	% Delta
ES(s)	Clear Sky w/Hg	12272.56	12240.45	-32.1	-0.26%	12076.2	12111.11	34.9	0.29%	11977.06	11958.25	-18.8	-0.16%	12272.56	11977.06	-2.41%	12240.45	11958.25	-2.31%
1	Clear Sky wo/Hg	11979.55	12076.59	97.0	0.81%	11828.6	11860.23	31.6	0.27%	11721.05	11715.82	-5.2	-0.04%	11979.55	11721.05	-2.16%	12076.59	11715.82	-2.99%
	NAAQS	12078.60	12057.58	-21.0	-0.17%	11760.9	11784.29	23.4	0.20%	11657.51	11680.62	23.1	0.20%	12078.60	11657.51	-3.49%	12057.58	11680.62	-3.13%
	Utility Based (Coal)	12194.56	11898.47	-296.1	-2.43%	11853.4	11888.72	35.4	0.30%	11712.96	11668.38	-44.6	-0.38%	12194.56	11712.96	-3.95%	11898.47	11668.38	-1.93%
	Utility Based High	12194.56	11898.47	-296.1	-2.43%	11742.6	11755.55	12.9	0.11%	11619.91	11562.96	-56.9	-0.49%	12194.56	11619.91	-4.71%	11898.47	11562.96	-2.82%
ES(f)	Clear Sky w/Hg	9769.41	9769.73	0.3	0.00%	9441.0	9472.74	31.7	0.34%	9367.06	9342.03	-25.0	-0.27%	9769.41	9367.06	-4.12%	9769.73	9342.03	-4.38%
2	Clear Sky wo/Hg	9357.79	9538.40	180.6	1.93%	9269.2	9243.68	-25.5	-0.27%	8967.24	8964.67	-2.6	-0.03%	9357.79	8967.24	-4.17%	9538.40	8964.67	-6.01%
	NAAQS	9529.03	9462.67	-66.4	-0.70%	9120.7	9105.95	-14.7	-0.16%	8933.65	8858.50	-75.2	-0.84%	9529.03	8933.65	-6.25%	9462.67	8858.50	-6.38%
	Utility Based (Coal)	9731.31	9359.69	-371.6	-3.82%	9314.1	9350.43	36.4	0.39%	9017.18	8997.97	-19.2	-0.21%	9731.31	9017.18	-7.34%	9359.69	8997.97	-3.86%
	Utility Based High	9731.31	9359.69	-371.6	-3.82%	9107.9	9118.18	10.3	0.11%	8876.71	8877.61	0.9	0.01%	9731.31	8876.71	-8.78%	9359.69	8877.61	-5.15%
P(s)	Clear Sky w/Hg	22806.87	22491.29	-315.6	-1.38%	22342.5	22283.83	-58.7	-0.26%	22344.07	22351.69	7.6	0.03%	22806.87	22344.07	-2.03%	22491.29	22351.69	-0.62%
3	Clear Sky wo/Hg	22119.31	22159.45	40.1	0.18%	22162.7	22066.27	-96.5	-0.44%	21869.02	22047.77	178.8	0.82%	22119.31	21869.02	-1.13%	22159.45	22047.77	-0.50%
	NAAQS	22271.25	22383.45	112.2	0.50%	22271.2	22213.67	-57.4	-0.26%	22042.46	22026.19	-16.3	-0.07%	22271.25	22042.46	-1.03%	22383.45	22026.19	-1.60%
	Utility Based (Coal)	22210.03	22270.08	60.0	0.27%	21954.9	22020.78	65.9	0.30%	21878.24	21833.21	-45.0	-0.21%	22210.03	21878.24	-1.49%	22270.08	21833.21	-1.96%
	Utility Based High	22210.03	22270.08	60.0	0.27%	21910.8	21917.27	6.5	0.03%	21844.70	21738.84	-105.9	-0.48%	22210.03	21844.70	-1.64%	22270.08	21738.84	-2.39%
P(i)	Clear Sky w/Hg	40019.14	39609.24	-409.9	-1.02%	37932.7	37988.67	56.0	0.15%	37322.97	37502.49	179.5	0.48%	40019.14	37322.97	-6.74%	39609.24	37502.49	-5.32%
4	Clear Sky wo/Hg	37277.97	37984.95	707.0	1.90%	36074.7	36375.24	300.5	0.83%	35038.74	35098.77	60.0	0.17%	37277.97	35038.74	-6.01%	37984.95	35098.77	-7.60%
	NAAQS	38035.08	37834.37	-200.7	-0.53%	36007.4	36114.31	106.9	0.30%	34766.22	34955.97	189.8	0.55%	38035.08	34766.22	-8.59%	37834.37	34955.97	-7.61%
	Utility Based (Coal)	38925.22	37364.69	-1560.5	-4.01%	36593.4	36875.42	282.0	0.77%	35174.80	34825.12	-349.7	-0.99%	38925.22	35174.80	-9.63%	37364.69	34825.12	-6.80%
	Utility Based High	38925.22	37364.69	-1560.5	-4.01%	35699.1	35756.37	57.2	0.16%	34099.13	33889.70	-209.4	-0.61%	38925.22	34099.13	-12.40%	37364.69	33889.70	-9.30%
FD(l)	Clear Sky w/Hg	39187.47	38982.95	-204.5	-0.52%	37321.5	37579.47	257.9	0.69%	36368.16	36400.04	31.9	0.09%	39187.47	36368.16	-7.19%	38982.95	36400.04	-6.63%
6	Clear Sky wo/Hg	36866.71	38105.86	1239.1	**3.36%**	35930.3	36315.65	385.3	1.07%	34111.63	33831.66	-280.0	-0.82%	36866.71	34111.63	-7.47%	38105.86	33831.66	-11.22%
	NAAQS	37434.41	37174.71	-259.7	-0.69%	35280.3	35284.27	4.0	0.01%	33812.43	33824.93	12.5	0.04%	37434.41	33812.43	-9.68%	37174.71	33824.93	-9.01%
	Utility Based (Coal)	38972.77	36708.83	-2263.9	-5.81%	35641.4	36275.93	634.5	1.78%	34018.50	33501.55	-517.0	-1.52%	38972.77	34018.50	-12.71%	36708.83	33501.55	-8.74%
	Utility Based High	38972.77	36708.83	-2263.9	-5.81%	34862.9	34962.54	99.7	0.29%	32945.65	32844.08	-101.6	-0.31%	38972.77	32945.65	-15.46%	36708.83	32844.08	-10.53%
S(s)	Clear Sky w/Hg	15708.68	15662.91	-45.8	-0.29%	15263.3	15217.38	-45.9	-0.30%	15234.51	15183.88	-50.6	-0.33%	15708.68	15234.51	-3.02%	15662.91	15183.88	-3.06%
7	Clear Sky wo/Hg	14913.27	15073.02	159.7	1.07%	14995.6	14949.79	-45.8	-0.31%	14701.46	14757.59	56.1	0.38%	14913.27	14701.46	-1.42%	15073.02	14757.59	-2.09%
	NAAQS	15292.36	15244.76	-47.6	-0.31%	14919.1	14943.34	24.3	0.16%	14930.54	14755.79	-174.7	-1.17%	15292.36	14930.54	-2.37%	15244.76	14755.79	-3.21%
	Utility Based (Coal)	15368.98	15369.14	0.2	0.00%	14948.5	15067.31	118.8	0.79%	14830.27	14646.25	-184.0	-1.24%	15368.98	14830.27	-3.51%	15369.14	14646.25	-4.70%
	Utility Based High	15368.98	15369.14	0.2	0.00%	14701.9	14889.04	187.2	1.27%	14706.62	14699.75	-6.9	-0.05%	15368.98	14706.62	-4.31%	15369.14	14699.75	-4.36%
S(l)	Clear Sky w/Hg	40626.31	39708.11	-918.2	-2.26%	39325.9	39301.92	-24.0	-0.06%	38473.62	38786.44	312.8	0.81%	40626.31	38473.62	-5.30%	39708.11	38786.44	-2.32%
8	Clear Sky wo/Hg	38432.39	38305.26	-127.1	-0.33%	37297.0	37150.01	-147.0	-0.39%	35648.17	35841.24	193.1	0.54%	38432.39	35648.17	-7.24%	38305.26	35841.24	-6.43%
	NAAQS	38608.03	38844.22	236.2	0.61%	37302.5	37067.13	-235.4	-0.63%	35572.22	35495.75	-76.5	-0.21%	38608.03	35572.22	-7.86%	38844.22	35495.75	-8.62%
	Utility Based (Coal)	38914.43	38921.29	6.9	0.02%	37819.4	37976.95	157.6	0.42%	36090.98	35870.30	-220.7	-0.61%	38914.43	36090.98	-7.26%	38921.29	35870.30	-7.84%
	Utility Based High	38914.43	38921.29	6.9	0.02%	36912.9	37181.24	268.4	0.73%	35798.58	35118.93	-679.6	-1.90%	38914.43	35798.58	-8.01%	38921.29	35118.93	-9.77%
SB(s)	Clear Sky w/Hg	586.51	586.59	0.1	0.01%	528.9	531.54	2.7	0.50%	538.35	545.22	6.9	1.28%	586.51	538.35	-8.21%	586.59	545.22	-7.05%
14	Clear Sky wo/Hg	522.04	514.93	-7.1	-1.36%	475.3	469.22	-6.1	-1.28%	441.24	441.27	0.0	0.01%	522.04	441.24	-15.48%	514.93	441.27	-14.31%
	NAAQS	539.86	540.45	0.6	0.11%	460.6	467.18	6.6	1.43%	441.59	436.28	-5.3	-1.20%	539.86	441.59	-18.20%	540.45	436.28	-19.27%
	Utility Based (Coal)	572.74	554.97	-17.8	-3.10%	514.6	516.13	1.6	0.30%	478.36	469.55	-8.8	-1.84%	572.74	478.36	-16.48%	554.97	469.55	-15.39%
	Utility Based High	572.74	554.97	-17.8	-3.10%	503.9	501.25	-2.6	-0.52%	436.93	453.34	16.4	**3.76%**	572.74	436.93	-23.71%	554.97	453.34	-18.31%

Note: Positive % Delta >/= 3.0 in **bold**, negative % Delta </= -3.0 in *italic*

TABLE 10-40
NAVPAT Traffic Impacts Middle Ohio River

Fish Species/ Life Stage[1]	Traffic Forecast Scenario	2010				2040				2070				2010-2070			2010-2070		
		Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project 2010	Without Project 2070	% Delta	With Project 2010	With Project 2070	% Delta
ES(s)	Clear Sky w/Hg	9445.39	9432.28	-13.1	-0.14%	9380.2	9404.34	24.2	0.26%	9321.78	9292.59	-29.2	-0.31%	9445.39	9321.78	-1.31%	9432.28	9292.59	-1.48%
1	Clear Sky wo/Hg	9408.03	9407.90	-0.1	0.00%	9278.6	9364.97	86.4	0.93%	9171.98	9196.66	24.7	0.27%	9408.03	9171.98	-2.51%	9407.90	9196.66	-2.25%
	NAAQS	9419.25	9396.92	-22.3	-0.24%	9302.9	9342.72	39.8	0.43%	9164.65	9207.01	42.4	0.46%	9419.25	9164.65	-2.70%	9396.92	9207.01	-2.02%
	Utility Based (Coal)	9423.80	9271.68	-152.1	-1.61%	9251.3	9253.74	2.5	0.03%	9229.99	9137.48	-92.5	-1.00%	9423.80	9229.99	-2.06%	9271.68	9137.48	-1.45%
	Utility Based High	9423.80	9271.68	-152.1	-1.61%	9260.5	9223.90	-36.6	-0.40%	9173.47	9232.71	59.2	0.65%	9423.80	9173.47	-2.66%	9271.68	9232.71	-0.42%
ES(f)	Clear Sky w/Hg	5897.70	5897.65	-0.1	0.00%	5812.9	5812.00	-0.9	-0.02%	5750.76	5740.36	-10.4	-0.18%	5897.70	5750.76	-2.49%	5897.65	5740.36	-2.67%
2	Clear Sky wo/Hg	5882.98	5979.36	96.4	1.64%	5679.4	5796.38	117.0	2.06%	5624.24	5661.09	36.8	0.66%	5882.98	5624.24	*-4.40%*	5979.36	5661.09	*-5.32%*
	NAAQS	5907.47	5858.14	-49.3	-0.84%	5699.1	5712.94	13.9	0.24%	5656.10	5715.37	59.3	1.05%	5907.47	5656.10	*-4.26%*	5858.14	5715.37	*-2.44%*
	Utility Based (Coal)	5847.57	5765.88	-81.7	-1.40%	5585.6	5660.22	74.6	1.34%	5533.11	5484.33	-48.8	-0.88%	5847.57	5533.11	*-5.38%*	5765.88	5484.33	*-4.88%*
	Utility Based High	5847.57	5765.88	-81.7	-1.40%	5611.9	5652.49	40.6	0.72%	5429.38	5488.38	59.0	1.09%	5847.57	5429.38	*-7.15%*	5765.88	5488.38	*-4.81%*
P(s)	Clear Sky w/Hg	30348.12	30292.82	-55.3	-0.18%	30075.8	30061.83	-13.9	-0.05%	29989.64	30022.26	32.6	0.11%	30348.12	29989.64	-1.18%	30292.82	30022.26	-0.89%
3	Clear Sky wo/Hg	30260.06	30164.57	-95.5	-0.32%	30139.2	30124.45	-14.8	-0.05%	29803.24	29959.62	156.4	0.52%	30260.06	29803.24	-1.51%	30164.57	29959.62	-0.68%
	NAAQS	30300.24	30420.70	120.5	0.40%	30120.3	29989.29	-131.0	-0.44%	29884.29	29746.39	-137.9	-0.46%	30300.24	29884.29	-1.37%	30420.70	29746.39	-2.22%
	Utility Based (Coal)	30349.91	30312.24	-37.7	-0.12%	30090.3	30134.62	44.3	0.15%	29896.55	29870.07	-26.5	-0.09%	30349.91	29896.55	-1.49%	30312.24	29870.07	-1.46%
	Utility Based High	30349.91	30312.24	-37.7	-0.12%	30003.1	29887.75	-115.4	-0.38%	29861.22	29894.18	33.0	0.11%	30349.91	29861.22	-1.61%	30312.24	29894.18	-1.38%
P(l)	Clear Sky w/Hg	41590.71	42118.65	527.9	1.27%	40981.3	40949.45	-31.9	-0.08%	39686.43	39229.54	-456.9	-1.15%	41590.71	39686.43	*-4.58%*	42118.65	39229.54	*-6.86%*
4	Clear Sky wo/Hg	41582.14	41093.11	-489.0	-1.18%	40067.6	40181.18	113.6	0.28%	38764.39	38959.85	195.5	0.50%	41582.14	38764.39	*-6.78%*	41093.11	38959.85	*-5.19%*
	NAAQS	41611.60	42110.21	498.6	1.20%	40731.9	40380.89	-351.0	-0.86%	38624.05	38212.16	-411.9	-1.07%	41611.60	38624.05	*-7.18%*	42110.21	38212.16	*-9.26%*
	Utility Based (Coal)	39765.03	40143.97	378.9	0.95%	38513.3	38274.70	-238.6	-0.62%	37244.57	37233.41	-11.2	-0.03%	39765.03	37244.57	*-6.34%*	40143.97	37233.41	*-7.25%*
	Utility Based High	39765.03	40143.97	378.9	0.95%	38054.9	38138.15	83.3	0.22%	35979.48	35607.77	-371.7	-1.03%	39765.03	35979.48	*-9.52%*	40143.97	35607.77	*-11.30%*
FD(l)	Clear Sky w/Hg	41942.72	42009.99	67.3	0.16%	40860.9	41248.45	387.6	0.95%	39274.06	39288.84	14.8	0.04%	41942.72	39274.06	*-6.36%*	42009.99	39288.84	*-6.48%*
6	Clear Sky wo/Hg	40555.75	41766.71	1211.0	2.99%	40126.9	40287.97	161.1	0.40%	38668.11	38931.99	263.9	0.68%	40555.75	38668.11	*-4.65%*	41766.71	38931.99	*-6.79%*
	NAAQS	41300.32	41011.83	-288.5	-0.70%	40396.2	40672.78	276.6	0.68%	38378.24	38555.44	177.2	0.46%	41300.32	38378.24	*-7.08%*	41011.83	38555.44	*-5.99%*
	Utility Based (Coal)	40330.99	39274.34	-1056.7	-2.62%	38183.7	38205.81	22.1	0.06%	36680.68	36720.24	39.6	0.11%	40330.99	36680.68	*-9.05%*	39274.34	36720.24	*-6.50%*
	Utility Based High	40330.99	39274.34	-1056.7	-2.62%	38189.3	38095.74	-93.5	-0.24%	36305.65	35641.71	-663.9	-1.83%	40330.99	36305.65	*-9.98%*	39274.34	35641.71	*-9.25%*
S(s)	Clear Sky w/Hg	19292.95	19262.54	-30.4	-0.16%	19040.9	18991.37	-49.5	-0.26%	18874.55	18786.44	-88.1	-0.47%	19292.95	18874.55	*-2.17%*	19262.54	18786.44	*-2.47%*
7	Clear Sky wo/Hg	18977.04	19025.54	48.5	0.26%	18919.7	18800.88	-118.8	-0.63%	18704.14	18666.37	-37.8	-0.20%	18977.04	18704.14	*-1.44%*	19025.54	18666.37	*-1.89%*
	NAAQS	19153.90	19345.47	191.6	1.00%	18947.4	18893.42	-54.0	-0.28%	18790.28	18643.51	-146.8	-0.78%	19153.90	18790.28	*-1.90%*	19345.47	18643.51	*-3.63%*
	Utility Based (Coal)	19198.57	19254.71	56.1	0.29%	18812.2	18842.48	30.3	0.16%	18607.61	18593.61	-14.0	-0.08%	19198.57	18607.61	*-3.08%*	19254.71	18593.61	*-3.43%*
	Utility Based High	19198.57	19254.71	56.1	0.29%	18622.6	18570.24	-52.3	-0.28%	18503.75	18510.23	6.5	0.04%	19198.57	18503.75	*-3.62%*	19254.71	18510.23	*-3.87%*
S(l)	Clear Sky w/Hg	43248.68	43014.87	-233.8	-0.54%	42207.2	42237.80	30.6	0.07%	40541.25	40631.77	90.5	0.22%	43248.68	40541.25	*-6.26%*	43014.87	40631.77	*-5.54%*
8	Clear Sky wo/Hg	42641.91	42792.98	151.1	0.35%	41348.4	41445.95	97.6	0.24%	39813.73	40096.31	282.6	0.71%	42641.91	39813.73	*-6.63%*	42792.98	40096.31	*-6.30%*
	NAAQS	42874.43	43123.03	248.6	0.58%	41398.4	40954.83	-443.5	-1.07%	39412.16	39610.26	198.1	0.50%	42874.43	39412.16	*-8.08%*	43123.03	39610.26	*-8.15%*
	Utility Based (Coal)	41614.14	40845.95	-768.2	-1.85%	39799.7	39474.05	-325.7	-0.82%	38100.03	37950.46	-149.6	-0.39%	41614.14	38100.03	*-8.44%*	40845.95	37950.46	*-7.09%*
	Utility Based High	41614.14	40845.95	-768.2	-1.85%	38956.4	38990.67	34.2	0.09%	37472.09	37519.03	46.9	0.13%	41614.14	37472.09	*-9.95%*	40845.95	37519.03	*-8.15%*
SB(s)	Clear Sky w/Hg	294.84	296.04	1.2	0.41%	294.9	298.39	3.4	1.17%	289.72	293.77	4.1	1.40%	294.84	289.72	-1.74%	296.04	293.77	-0.77%
14	Clear Sky wo/Hg	294.27	299.25	5.0	1.69%	283.5	281.64	-1.9	-0.66%	266.27	273.41	7.1	2.68%	294.27	266.27	*-9.51%*	299.25	273.41	*-8.63%*
	NAAQS	294.03	298.24	4.2	1.43%	274.9	277.56	2.6	0.96%	268.07	275.02	7.0	2.59%	294.03	268.07	*-8.83%*	298.24	275.02	*-7.79%*
	Utility Based (Coal)	279.69	266.07	-13.6	*-4.87%*	266.3	272.82	6.6	2.46%	256.41	256.72	0.3	0.12%	279.69	256.41	*-8.32%*	266.07	256.72	*-3.51%*
	Utility Based High	279.69	266.07	-13.6	*-4.87%*	265.2	266.50	1.3	0.49%	258.72	256.90	-1.8	-0.71%	279.69	258.72	*-7.50%*	266.07	256.90	*-3.45%*

Note: Positive % Delta >/= 3.0 in **bold**, negative % Delta </= -3.0 in *italic*

TABLE 10-41
NAVPAT Traffic Impacts Lower Ohio River

Fish Species/ Life Stage[1]	Traffic Forecast Scenario	2010				2040				2070				2010-2070			2010-2070		
		Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project HSI Units	With Project HSI Units	Delta	% Delta	Without Project 2010	Without Project 2070	% Delta	With Project 2010	With Project 2070	% Delta
ES(s)	Clear Sky w/Hg	13789.33	13811.36	22.0	0.16%	13669.6	13675.12	5.5	0.04%	13659.20	13632.06	-27.1	-0.20%	13789.33	13659.20	-0.94%	13811.36	13632.06	-1.30%
1	Clear Sky wo/Hg	13711.34	13704.29	-7.0	-0.05%	13619.3	13669.16	49.9	0.37%	13423.51	13532.62	109.1	0.81%	13711.34	13423.51	-2.10%	13704.29	13532.62	-1.25%
	NAAQS	13728.88	13810.35	81.5	0.59%	13673.5	13663.62	-9.8	-0.07%	13402.17	13392.87	-9.3	-0.07%	13728.88	13402.17	-2.38%	13810.35	13392.87	*-3.02%*
	Utility Based (Coal)	13704.74	13645.82	-58.9	-0.43%	13597.7	13627.68	30.0	0.22%	13494.10	13461.94	-32.2	-0.24%	13704.74	13494.10	-1.54%	13645.82	13461.94	-1.35%
	Utility Based High	13704.74	13645.82	-58.9	-0.43%	13665.4	13682.90	17.5	0.13%	13464.79	13495.49	30.7	0.23%	13704.74	13464.79	-1.75%	13645.82	13495.49	-1.10%
ES(f)	Clear Sky w/Hg	4275.85	4260.41	-15.4	-0.36%	4239.0	4242.81	3.8	0.09%	4213.30	4209.83	-3.5	-0.08%	4275.85	4213.30	-1.46%	4260.41	4209.83	-1.19%
2	Clear Sky wo/Hg	4248.13	4264.12	16.0	0.38%	4217.5	4238.81	21.3	0.51%	4204.15	4186.58	-17.6	-0.42%	4248.13	4204.15	-1.04%	4264.12	4186.58	-1.82%
	NAAQS	4266.73	4258.19	-8.5	-0.20%	4233.7	4249.39	15.7	0.37%	4196.21	4191.65	-4.6	-0.11%	4266.73	4196.21	-1.65%	4258.19	4191.65	-1.56%
	Utility Based (Coal)	4241.13	4254.30	13.2	0.31%	4219.4	4210.36	-9.0	-0.21%	4200.07	4192.43	-7.6	-0.18%	4241.13	4200.07	-0.97%	4254.30	4192.43	-1.45%
	Utility Based High	4241.13	4254.30	13.2	0.31%	4231.6	4234.98	3.4	0.08%	4200.00	4167.42	-32.6	-0.78%	4241.13	4200.00	-0.97%	4254.30	4167.42	-2.04%
P(s)	Clear Sky w/Hg	46966.72	46970.01	3.3	0.01%	46611.5	46621.96	10.5	0.02%	46466.77	46438.07	-28.7	-0.06%	46966.72	46466.77	-1.06%	46970.01	46438.07	-1.13%
3	Clear Sky wo/Hg	46796.24	46829.98	33.7	0.07%	46552.0	46600.16	48.1	0.10%	46163.38	46330.59	167.2	0.36%	46796.24	46163.38	-1.35%	46829.98	46330.59	-1.07%
	NAAQS	46787.74	47059.89	272.2	0.58%	46522.9	46514.73	-8.2	-0.02%	46215.89	46151.66	-64.2	-0.14%	46787.74	46215.89	-1.22%	47059.89	46151.66	-1.93%
	Utility Based (Coal)	46929.00	46886.69	-42.3	-0.09%	46614.7	46604.54	-10.1	-0.02%	46389.96	46320.73	-69.2	-0.15%	46929.00	46389.96	-1.15%	46886.69	46320.73	-1.21%
	Utility Based High	46929.00	46886.69	-42.3	-0.09%	46551.7	46410.39	-141.3	-0.30%	46330.65	46289.99	-40.7	-0.09%	46929.00	46330.65	-1.28%	46886.69	46289.99	-1.27%
P(i)	Clear Sky w/Hg	72767.94	72542.39	-225.5	-0.31%	70723.4	70635.58	-87.9	-0.12%	69014.94	68984.78	-30.2	-0.04%	72767.94	69014.94	*-5.16%*	72542.39	68984.78	*-4.90%*
4	Clear Sky wo/Hg	72330.22	72452.03	121.8	0.17%	69855.0	70063.77	208.7	0.30%	68119.98	68622.47	502.5	0.74%	72330.22	68119.98	*-5.82%*	72452.03	68622.47	*-5.29%*
	NAAQS	72546.06	72177.48	-368.6	-0.51%	69710.1	70394.64	684.5	0.98%	67562.65	67966.07	403.4	0.60%	72546.06	67562.65	*-6.87%*	72177.48	67968.07	*-5.83%*
	Utility Based (Coal)	72139.04	72208.35	69.3	0.10%	69423.1	70082.96	659.9	0.95%	68395.08	67296.81	-1098.3	-1.61%	72139.04	68395.08	*-5.19%*	72208.35	67296.81	*-6.80%*
	Utility Based High	72139.04	72208.35	69.3	0.10%	69999.0	69908.04	-90.9	-0.13%	67227.67	67770.06	542.4	0.81%	72139.04	67227.67	*-6.81%*	72208.35	67770.06	*-6.15%*
FD(i)	Clear Sky w/Hg	71694.64	72641.02	946.4	1.32%	70624.3	70727.51	103.3	0.15%	68743.38	68050.03	-693.3	-1.01%	71694.64	68743.38	*-4.12%*	72641.02	68050.03	*-6.32%*
6	Clear Sky wo/Hg	72023.30	72174.41	151.1	0.21%	70271.6	70289.80	18.2	0.03%	67538.95	69032.97	1494.0	2.21%	72023.30	67538.95	*-6.23%*	72174.41	69032.97	*-4.35%*
	NAAQS	72043.46	72864.84	821.4	1.14%	70639.7	70373.59	-266.1	-0.38%	67950.74	68359.17	408.4	0.60%	72043.46	67950.74	*-5.68%*	72864.84	68359.17	*-6.18%*
	Utility Based (Coal)	72818.65	72540.64	-278.0	-0.38%	70498.8	69890.31	-608.5	-0.86%	69534.96	68294.17	-1240.8	-1.78%	72818.65	69534.96	*-4.51%*	72540.64	68294.17	*-5.85%*
	Utility Based High	72818.65	72540.64	-278.0	-0.38%	69276.4	69939.02	662.6	0.96%	68203.98	67301.66	-902.3	-1.32%	72818.65	68203.98	*-6.34%*	72540.64	67301.66	*-7.22%*
S(s)	Clear Sky w/Hg	21210.17	21218.70	8.5	0.04%	21141.0	21161.42	20.5	0.10%	20720.63	20753.36	32.7	0.16%	21210.17	20720.63	*-2.31%*	21218.70	20753.36	*-2.19%*
7	Clear Sky wo/Hg	20968.05	21103.40	135.3	0.65%	20895.0	20843.88	-51.1	-0.24%	20644.11	20688.67	44.6	0.22%	20968.05	20644.11	*-1.54%*	21103.40	20688.67	*-1.97%*
	NAAQS	21051.79	21286.10	234.3	1.11%	20817.0	20760.92	-56.1	-0.27%	20769.90	20648.15	-121.7	-0.59%	21051.79	20769.90	*-1.34%*	21286.10	20648.15	*-3.00%*
	Utility Based (Coal)	21107.31	21266.13	158.8	0.75%	20857.9	21079.80	221.8	1.06%	20690.78	20671.43	-19.4	-0.09%	21107.31	20690.78	*-1.97%*	21266.13	20671.43	*-2.80%*
	Utility Based High	21107.31	21266.13	158.8	0.75%	20863.7	20934.87	71.1	0.34%	20667.05	20772.10	105.1	0.51%	21107.31	20667.05	*-2.09%*	21266.13	20772.10	*-2.32%*
S(l)	Clear Sky w/Hg	75394.46	75643.94	249.5	0.33%	73841.6	73748.88	-92.7	-0.13%	71976.38	72242.62	266.2	0.37%	75394.46	71976.38	*-4.53%*	75643.94	72242.62	*-4.50%*
8	Clear Sky wo/Hg	74897.72	75320.95	423.2	0.57%	73581.0	73369.57	-211.5	-0.29%	71300.20	72329.28	1029.1	1.44%	74897.72	71300.20	*-4.80%*	75320.95	72329.28	*-3.97%*
	NAAQS	75373.25	76575.37	1202.1	1.59%	73314.8	73179.28	-135.5	-0.18%	70576.46	71337.94	761.5	1.08%	75373.25	70576.46	*-6.36%*	76575.37	71337.94	*-6.84%*
	Utility Based (Coal)	75446.10	75333.55	-112.6	-0.15%	72733.4	72877.47	144.1	0.20%	71274.24	71017.74	-256.5	-0.36%	75446.10	71274.24	*-5.53%*	75333.55	71017.74	*-5.73%*
	Utility Based High	75446.10	75333.55	-112.6	-0.15%	72749.6	72630.35	-119.3	-0.16%	71188.34	71259.64	71.3	0.10%	75446.10	71188.34	*-5.64%*	75333.55	71259.64	*-5.41%*
SB(s)	Clear Sky w/Hg	286.85	295.43	8.6	2.99%	293.5	292.56	-0.9	-0.31%	278.76	274.75	-4.0	-1.44%	286.85	278.76	*-2.82%*	295.43	274.75	*-7.00%*
14	Clear Sky wo/Hg	289.43	279.64	-9.8	*-3.38%*	281.7	286.22	4.5	1.59%	267.60	271.78	4.2	1.56%	289.43	267.60	*-7.54%*	279.64	271.78	*-2.81%*
	NAAQS	287.40	290.33	2.9	1.02%	277.9	274.74	-3.2	-1.15%	263.89	277.06	13.2	**4.99%**	287.40	263.89	*-8.18%*	290.33	277.06	*-4.57%*
	Utility Based (Coal)	296.70	287.71	-9.0	*-3.03%*	281.2	270.73	-10.5	*-3.73%*	273.56	271.28	-2.3	-0.84%	296.70	273.56	*-7.80%*	287.71	271.28	*-5.71%*
	Utility Based High	296.70	287.71	-9.0	*-3.03%*	269.5	269.79	0.3	0.11%	266.13	268.08	1.9	0.73%	296.70	266.13	*-10.30%*	287.71	268.08	*-6.82%*

Note: Positive % Delta >/= 3.0 in **bold**, negative % Delta </= -3.0 in *italic*

5. To illustrate the application of these criteria to the composited data in **Tables 10-38** through **10-40**, the following comments can be made for the Emerald Shiner-Spawning – ES(s) – life stage:

- For the time periods of 2010, 2040, and 2070, all % deltas are less than 3% for all three river segments (no exceedances of 3% out of 45 conditions examined).

- For the comparisons of the WOPCs in 2010 and 2070, and likewise for the WPCs, 25 of the 30 deltas are less than 3%. The five that are 3% or greater include four in the Upper segment and one in the Lower segment. The maximum % delta was minus 4.71% for the Utility Based High (UBH) scenario in the Upper segment under the WOPC scenario. When the delta itself (-574.65 HUs) is considered relative to the total HUs for the Ohio River mainstem (35,296 HUs), the % change considering the entire resource base drops to 1.6%.

6. The information from the two bullets above is summarized in **Table 10-42**. Comparable summary information from **Tables 10-39** through **10-41** is also included for the other seven species/life stages. The following observations can be made relative to **Table 10-42**:

- The differences in HUs between the WOPCs and WPCs for 2010, 2040, and 2070 were less than 3% (no exceedances) for Emerald Shiner-Spawning, Sauger-Spawning, and Sauger-Larval for all three river segments. A total of only 7 exceedances occurred for Emerald Shiner-Fry, Paddlefish-Larval, and Freshwater Drum-Larval, with the majority associated with the UB (Utility Based) and UBH (Utility Based High) traffic scenarios for the Upper segment in 2010. Ten exceedances occurred for Spotted Bass-Spawning, again with the majority associated with the UB and UBH traffic scenarios; however they were not limited to the Upper segment. In fact, they also occurred in the Middle and Lower segments in 2010 and 2040. The Spotted Bass-Spawning exceedances are somewhat overstated due to the small HUs resource base for the species. Further, the main spawning areas are in the side channels, and NAVPAT does not include this habitat.

- An additional consideration related to HU differences between the WOPC and WPC is that navigation traffic is but one contributor to cumulative effects on fish habitat. NAVPAT only evaluates changes in aquatic habitat that occur as a result of commercial traffic movement on the river. Chapter 4 in the CEA report in the **Environmental Appendix** illustrates numerous other actions within and along the mainstem that contribute to fish sustainability.

- The large majority of all exceedances (i.e., delta of 3% or greater) summarized in **Table 10-42** are related to navigation traffic changes for the WOPC in 2010 and 2070, and for the WPC at the same times. Paddlefish-Spawning was the only species that exhibited no exceedances. Further, exceedances often occurred in all

three river segments for all traffic scenarios for the other seven species/life stages. Finally, when the exceedances were adjusted to a total HU basis the percentages typically decreased to about one-third of the percentage loss levels for the individual segments.

TABLE 10-42
Summary of NAVPAT Traffic Impact Results

Fish Species/ Life Stages	Number of Exceedances[a]		
	WOPC-WPC (2010, 2040, &2070)	**WOPC** (2010 - 2070)	**WPC** (2010 - 2070)
ES(s)	0 of 45 conditions	3 of 15 conditions (all in Upper segment for NAAQS, UB, and UBH scenarios; the maximum (-4.71%) is 1.6% of total HUs for mainstem)	2 of 15 conditions (one each in Upper and Lower segment for NAAQS); the maximum (-3.13%) for UBH in the Upper segment is 1.1% of total HUs for mainstem
ES(f)	2 of 45 conditions (-3.82% for UB and UBH in the Upper segment in 2010); this represents 1.9% of total HUs for mainstem	9 of 15 conditions (5 in Upper segment and 4 in Middle segment); the maximum (-8.78% for UBH in the Upper segment) is 4.3% of the total HUs for mainstem	8 of 15 conditions(5 in Upper segment and 3 in Middle segment); the maximum (-6.38% for NAAQS in the Upper segment) is 3.1% of the total HUs for mainstem
P(s)	0 of 45 conditions	0 of 15 conditions	0 of 15 conditions
P(l)	2 of 45 conditions (-4.01% for UB and UBH in the Upper segment in 2010); this represents 1.0% of the total HUs for mainstem	15 of 15 conditions (5 each in Upper, Middle, and Lower segments); the maximum (-12.4% for UBH in the Upper segment) is 3.2% of the total HUs for mainstem	15 of 15 conditions (5 each in Upper, Middle, and Lower segments); the maximum (-11.3% for UBH in the Upper segment) is 3.0% of the total HUs for mainstem
FD(l)	3 of 45 conditions (+3.36% for CSw/o Hg, and -5.81% for UB and UBH in the Upper segment in 2010); the maximum (-5.81%) is 1.5% of the total HUs for mainstem	15 of 15 conditions (5 each in Upper, Middle, and Lower segments); the maximum (-15.46% for UBH in the Upper segment) is 4.0% of the total HUs for mainstem	15 of 15 conditions (5 each in Upper, Middle, and Lower segments); the maximum (-11.22% for CSw/o Hg in the Upper segment) is 2.8% of the total HUs for mainstem
S(s)	0 of 45 conditions	15 of 15 conditions (3 in Upper segment and 2 in Middle segment; the maximum (-4.31% for UBH in the Upper segment) is 1.2% of the total HUs for mainstem	8 of 15 conditions (4 in Upper segment, 3 in Middle segment, and one in Lower segment; the maximum (-4.7% for UB in the Upper segment) is 1.3% of the total HUs for mainstem
S(l)	0 of 45 conditions	15 of 15 conditions (5 each in Upper, Middle, and Lower segments); the maximum (-9.95% for UBH in the Middle segment) is 2.6% of the total HUs for mainstem	14 of 15 conditions (4 in Upper and 5 each in Middle and Lower segments); the maximum (-9.77% for UBH in the Upper segment) is 2.4% of the total HUs for mainstem
SB(s)	10 of 45 conditions (-3.10% for UB and UBH in the Upper segment in	13 of 15 conditions (5 in Upper segment, and 4 each in the Middle and Lower	13 of 15 conditions (5 in Upper segment, and 4 each in the Middle and Lower

Fish Species/ Life Stages	Number of Exceedances[a]		
	WOPC-WPC (2010, 2040, &2070)	**WOPC (2010 - 2070)**	**WPC (2010 - 2070)**
	2010, +3.76% for UBH in the Upper segment in 2070; -4.87% for UB and UBH in the Middle segment in 2040; -3.38% for CS w/o Hg, and -3.03% for UB and UBH in the Lower segment in 2010; -3.73% for UB in the Lower segment in 2040; and +4.99% for NAAQS in the Lower segment in 2070); the maximum negative (-4.87%) change is 1.2% of the total HUs for mainstem	segments); the maximum (-23.71% for UBH in the Upper segment) is 11.9% of the total HUs for mainstem	segments); the maximum (-19.27% for NAAQS in the Upper segment) is 9.1% of the total HUs for mainstem
a = an exceedance is when a % delta is equal to or greater than + or - 3%			

7. Based on the above findings, along with a systematic consideration of the NAVPAT results for the individual pools as contained in the above-mentioned NAVPAT section of the **Environmental Appendix**, additional observations and analysis can be noted. For example, a clear and consistent pattern evident in the Ohio River Mainstem Study NAVPAT output is that, under either With Project or Without Project conditions, increasing river traffic between the years 2010 and 2070 will result in a loss of habitat units for Emerald Shiner-Spawning and Fry, Paddlefish-Spawning and Larval, Freshwater Drum-Larval, Sauger-Spawning and Larval, and Spotted Bass-Spawning. These losses occur under all five traffic scenarios examined, but are notably greater under the two highest traffic prediction scenarios (Utility Based and Utility Based High). These results are not in any way surprising since the model intrinsically generates non-recovery propeller mortality output for all larval or fry life stages. Except for Paddlefish-Larval, Freshwater Drum-Larval, and Sauger-Larval, predicted losses of habitat units for the Ohio River will be negligible to slight. The slight to moderate losses in habitat units for Paddlefish-Larval, Freshwater Drum-Larval, and Sauger-Larval are probably balanced by the great abundance of these three types of habitats all along the river. Since they are the most common existing species/life stage habitats within the Ohio River, a modest decline in the availability of these habitats is not likely to be a factor limiting populations of paddlefish, freshwater drum, or sauger in the river. Further, results of recent studies performed for the Upper Mississippi River/Illinois Waterway demonstrate that mortality of fish larvae from propeller entrainment is less than the 100% assumed in the NAVPAT model.

8. Beyond these nearly self-evident generalizations, it is very difficult to find consistent and reliable patterns of future predicted navigation influences within the massive outputs of the Ohio River Mainstem Study NAVPAT application. As discussed previously, the failure of such patterns to emerge might be related to the large size and

high flows of the Ohio River mainstem, and its ability to absorb predicted additional navigation induced impacts, without significantly influencing existing fishery resources within an already highly modified ecosystem.

9. Some suggestive evidence that system size might be a variable contributing to the differences in Ohio River and Kanawha River NAVPAT results is that the few differences (greater than + or – 5.0 % delta for individual pools) observed between With Project or Without Project conditions noted for the Ohio River are clustered along the Upper and smaller reach of the Ohio River mainstem. Specifically, Emerald Shiner-Spawning habitat unit deltas of –5.9% occurred in Dashields Pool in 2010 under the Utility Based and Utility Based High traffic scenarios. Paddlefish-Larval habitat unit deltas of –5.4% occurred in Racine Pool in the same year under the same traffic scenarios, and Freshwater Drum-Larval habitat unit deltas ranging from –5.2% to –8.2% were observed all along the ten uppermost pools in the river from the Emsworth pool downstream to the Byrd pool, all again for the year 2010 under Utility Based and Utility Based High traffic scenarios. These impacts to Freshwater Drum-Larval in the Upper river over short term, high traffic, and under With Project conditions may be the only non-random habitat unit deltas predicted by the model. With the exception of the Spotted Bass-Spawning species/life stage, no other meaningful changes were observed for any other species/life stage under any traffic scenario in 2040 or 2070, in any pool, under either With Project or Without Project conditions. It should be remembered, that while this clustering was clearly exclusive to the Upper river, it nonetheless amounted to only a modest portion of the total number of 2520 specific species /life stage events predicted by the NAVPAT model for the Ohio River, and attempts to draw conclusions from this apparent pattern, therefore, should be considered speculative at best.

10. The Spotted Bass-Spawning species/life stage exception for individual pools, referred to in the preceding paragraph, consisted of a total of 35 habitat unit deltas in excess of 5.0%, 15 negative and 20 positive, very randomly distributed throughout the 2010 to 2070 study period, and occurring in a random manner within the five different commercial river traffic scenarios. Of all the NAVPAT quantified fish species/life stage habitats, spawning habitat for spotted bass is by far the most limited and the most unevenly distributed fish habitat in the Ohio River; for example, 49% is in the Upper reach, and the remaining 51% is evenly distributed in the Middle and Lower reaches. The very small and rather scattered number of Spotted Bass- Spawning habitat units appears to be very susceptible to random and apparently meaningless model perturbations.

11. In summary, the Ohio River Mainstem Study NAVPAT application successfully quantified habitat required for various life stages of the primary fish assemblages of the Ohio River, as well as the impacts of future navigation activity scenarios to these habitats. The results of this modeling effort demonstrated that increases in navigation traffic through the year 2070 will negatively, but rather modestly, impact certain groups of fishes, especially swiftwater spawning fishes. While benefits to the fishery might accrue from improvements to navigation under With Project conditions, any such benefits are apparently too small to be measured by the NAVPAT model. In

part this might be related to model sensitivity. For instance, NAVPAT programming generalized river cross-sections up to one to two miles in length and normalized traffic input files within the cross-sections. Therefore, this application was not designed to identify reduction in vessel queuing impacts to the aquatic resource. However, the failure of the model to demonstrate substantial future impacts from navigation are most likely overwhelmingly related to the ability of the Ohio River to absorb the predicted additional navigation induced impacts without significantly influencing existing fishery resources within an already highly modified ecosystem.

10.2.3.6.4 Anticipated Improvements to the NAVPAT Model

While the 2005 edition of NAVPAT provides a useful tool for assessment of the impacts of commercial navigation traffic on habitats of various fish species and life stages, a number of improvements to this model would be desirable. ERDC is now in the process of generally upgrading the NAVPAT model, and future applications of NAVPAT will probably find the new ERDC version easier to manage and execute. Also, specific nomenclature should be developed to distinguish between various editions of the model, and the version used in any application should be carefully referenced. A deficiency of both the original version of NAVPAT and the 2005 edition is that neither is able to model conditions nor predict future navigation impacts for the backchannels of river islands. These backchannel reaches are very important habitat components of river ecosystems, and expansion of the model to include this habitat type should be a consideration in future improvement of the NAVPAT model. In addition, during the course of the ORMSS and similar study efforts, such as the modeling of commercial navigation impacts on the Winfield Pool of the Kanawha River, field investigators noted extreme velocity and wave/wake effects from large V-hulled recreational vessels. At least anecdotally, it appears that the impacts of such vessels might equal or perhaps exceed those of commercial tow traffic. Therefore, it is highly recommended that impacts of recreation traffic be incorporated into future NAVPAT model development.

10.3 COMPARISON OF ALTERNATIVE SYSTEM INVESTMENT PLANS (SIPS)

This section is structured into subsections related to requirements from the Corps' planning process, requirements from the NEPA regulations of the Council on Environmental Quality (and supported in the Corps' NEPA regulations), the screening and prioritization process for potential measures which could comprise components of navigated-related and environmental sustainability (ES)-related plans, summary descriptions of the included measures in each plan, comparisons of the overall and detailed features of the navigated-related and ES-related plans, and the combination of the economic and environmental results into a "best NED/NER plan".

10.3.1 Requirements from the Corps' Planning Process

1. As noted in Section 2, the Corps' planning process consists of six steps. Step 1 (identifying problems and opportunities related to both the Ohio River navigation system

and the sustainability of multiple resources, ecosystems and human communities) was addressed in Sections 3 through 6. Likewise, Step 2 (inventorying and forecasting conditions) was also highlighted as appropriate, in Sections 3 through 6. The formulation of alternative plans for both navigation system and environmental sustainability needs was accomplished for Without Project Conditions (WOPC) in Section 8, while Section 9 and the first part of Section 10 did likewise for With Project Conditions (WPC). Evaluating alternative plans (Step 4) relative to economic indicators and ES considerations was also accomplished in Sections 8 and 9 for WOPC and WPC, respectively and in earlier subsections of Section 10 for WPC. This subsection contains summary information related to comparisons of the plans (Step 5). Further, the included discussions of trade-offs among plans provide the basis for Step 6 (selecting a plan).

2. The following definitions and principles from the Corps' Planning Guidance Notebook (ER 1105-2-100; April 22, 2000) are instructive in comparing the plans:

- From Step 3 (1) – Alternative plans shall be formulated to identify specific ways to achieve planning objectives within constraints, so as to solve the problems and realize the opportunities that were identified in Step 1. An alternative plan consists of a system of structural and/or nonstructural measures, strategies, or programs formulated to meet, fully or partially, the identified study planning objectives subject to the planning constraints. A range of alternative plans comprised of various management measures shall be identified at the beginning of the planning process and screened and refined in subsequent iterations throughout the planning process.

- From Step 3 (2) – Each alternative plan shall be formulated in consideration of four criteria: completeness, efficiency, effectiveness, and acceptability. Completeness is the extent to which the alternative plans provide and account for all necessary investment or other actions to ensure the realization of the planning objectives, including actions by other Federal and non-Federal entities. Effectiveness is the extent to which the alternative plans contribute to achieve the planning objectives. Efficiency is the extent to which an alternative plan is the most cost-effective means of achieving the objectives. Acceptability is the extent to which the alternative plans are acceptable in terms of applicable laws, regulations and public policies. Appropriate mitigation of adverse effects shall be an integral component of each alternative plan.

- From Step 5 – In this step, plans (including the no action plan) are compared, with emphasis on the outputs and effects that will have the most influence in the decision making process. Beneficial and adverse effects of each plan must be compared. These include monetary and non-monetary benefits and costs. Identification and documentation of tradeoffs will be required to support the final recommendation. The effects include those identified during the evaluation phase and any other significant effects identified in Step 5. The comparison step can be defined as a reiteration of the evaluation step (Step 4), with the exception that in this step each plan (including the no action plan) is compared against each other

and not against the without-project condition. The output of the comparison step shall be a ranking of plans.

- From Step 6 – A single alternative plan will be selected for recommendation from among all those that have been considered. The recommended plan must be shown to be preferable to taking no action (if no action is not recommended) or implementing any of the other alternatives considered during the planning process. The culmination of the planning process is the selection of the recommended plan or the decision to take no action. The criteria for selecting the recommended plan differ, depending on the type of plan and whether project outputs are NED, NER, or a combination of both.

    (1) The National Economic Development (NED) Plan. For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment, the NED plan, shall be selected.

    (2) The National Ecosystem Restoration (NER) Plan. For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be cost-effective and incrementally justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan.

    (3) The Combined NED/NER Plan. Projects which produce both National Economic Development (NED) benefits and National Ecosystem Restoration (NER) benefits will result in a "best" recommended plan so that no alternative plan or scale has a higher excess of NED benefits plus NER benefits over total project costs. This plan shall attempt to maximize the sum of net NED and NER benefits, and to offer the best balance between two Federal objectives. Recommendations for multipurpose projects will be based on a combination of NED benefit-cost analysis, and NER benefits and analysis, including cost effectiveness and incremental cost analysis.

4. To summarize the application of the above definitions and principles in the ORMSS, the following features are noted from Sections 8, 9, and earlier and planned portions of this section:

- The identified navigation-related plans (Reactive Maintenance Alternative from Section 8, and Advanced Maintenance Alternative, Major Rehabilitation Alternative, and Lock Modernization Alternative from Section 9) each include combinations of structural and nonstructural measures and strategies or programs.

- The identified ES-related (ecosystem restoration-related) plans in Sections 8 and 9 each include combinations of various measures to protect and/or enhance aquatic ecosystems of the Ohio River, and terrestrial (riparian) ecosystems associated therewith.

- Screening of various potential navigation-related measures was accomplished in both Sections 8 and 9, with the result that some measures were eliminated from further analysis while others were refined. In an analogous manner, the listed ES measures in Sections 8 and 9 were prioritized into four groups (A to D) based on potential environmental outputs in relation to cost, and their ease of initiation under current authorities.

- Plan evaluation based on the criteria of completeness, efficiency, effectiveness and acceptability is accomplished in a later subsection herein.

- Comparisons of the monetary and non-monetary outputs and effects of each navigation-related and each ES-related plan will also be accomplished in a later subsection herein. Such comparisons are presented in tabular formats and discussed in relation to their trade-offs relative to the "no action plan" and to each other. The ORMSS navigation-related no action plan, or continuation of the status quo activities, is most closely represented by the Reactive Maintenance Alternative comprised only of activities associated with routine maintenance, cyclical maintenance, and unscheduled repairs. The "no action plan" for ES can be defined as the non-implementation of any ES measures listed in **Table 8-9**. The output from these comparisons will be a rank ordering of both the navigation-related and ES-related plans.

- In a subsequent subsection herein, the NED plan is identified from the navigation-related plans, and the NER plan is identified from the ES-related plans. As a result, the combined best NED/NER plan is identified.

10.3.2 Requirements from the NEPA Process

1. The NEPA regulations of CEQ, as supported by the Corps' NEPA regulations, indicate that the analysis of alternatives is the heart of an environmental impact statement prepared under the auspices of NEPA requirements. Section 1502.14 of the CEQ's regulations further indicates that the environmental impacts of all reasonable alternatives, including the ultimate proposed action, should be presented in comparative form. This comparative presentation should aid in defining the issues and providing a clear basis for the choice of the proposed action. Additional guidance in the CEQ's regulations for the analysis of alternatives section includes the following:

- Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.

- Devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits.

- Include reasonable alternatives not within the jurisdiction of the lead agency.

- Include the alternative of no action.

- Identify the agency's preferred alternative or alternatives, if one or more exists, in the draft statement and identify such alternative(s) in the final statement unless another law prohibits the expression of such a preference.

- Include appropriate mitigation measures not already included in the proposed action or alternatives.

2. To summarize the application of the comparative analyses of alternatives and the CEQ guidance, the following points are noted from Sections 8, 9, and 10:

- Tables are included in later subsections herein to display the comparative features of the navigation-related and ES-related alternative plans described in Sections 8, 9, and earlier portions of Section 10.

- The rigorous exploration and objective evaluation of all reasonable navigation-related and ES-related alternative plans is demonstrated in summary tables of the environmental effects of the navigation-related WOPC and WPC alternative plans in Sections 8 and 9. Detailed information related to these effects is included in the CEA report in the Environmental Appendix. In addition, two composite indicators of the direct environmental effects of the WOPC and WPC, and the differences between the two, are addressed earlier in this section in the analyses of transit days and fish habitat changes calculated with the NAVPAT model. The NAVPAT study report is also included in the **Environmental Appendix**.

- Detailed economic comparisons for each navigation-related alternative are contained in the **Economics Appendix**. Section 8 includes summary economic information on the WOPC alternative plan, and Section 10 does similarly for the WPC alternative plans. This summary information provides the basis for an objective evaluation of the economic features of each of the four navigation-related alternative plans.

- Several navigation-related measures that could have been included in the alternative plans were evaluated, discussed, and then eliminated in Sections 8 (WOPC alternative plan) and 9 (WPC alternative plans).

- The best combined NED/NER plan is identified in a later subsection herein. This plan is expected to become the Corp's preferred alternative.

- Appropriate mitigation measures will be identified during the specific design and planning phases for future WPC projects or activities. In some cases, EISs will be required (e.g., lock modernization at EDM) while in other cases EA-levels of analysis will be appropriate.

3. Additional NEPA-related instruction on appropriate ranges of alternatives in EISs can be found in case law. Specifically, the 2001 edition of The NEPA Book by Bass, Henson, and Bogdan (Solano Press, 2001, pp. 94-95) contains the following case law principles related to the "range of alternatives":

- The range should be governed by the "rule of reason" – in the case of ORMSS, the navigation-related alternative plans are broad and encompass both structural and non-structural measures; the ES-related alternative plans also encompass numerous measures based on the input of subject matter experts on the aquatic and terrestrial (riparian) resources of the Ohio River.

- The range must achieve the proposed action's objectives as stated in the purpose and need (planning objectives) addressed in the EIS – the relative compliance of each navigation-related and ES-related plan to the three planning objectives delineated in Section 6 is addressed in a following subsection herein.

- The range must foster rather than constrain the options available to the decision makers – considerable flexibility is provided related to timing and specific design features of both the navigation-related and ES-related plans; further, considerable size and locational flexibility is available for the specific measures in the ES-related plans.

- The range must be feasible – both economic and technical feasibility exists for the navigation-related plans. The measures associated with the ES-related plans are scientifically feasible; however, specific determinations of the environmental outputs (benefits) of the measures, and their associated incremental and total costs have not yet been made. These evaluations of the ES-related plans will need to be done when planning site-specific actions including mitigation in order to provide appropriate bases for specific decision making.

- Alternatives that are remote or speculative need not be considered in an EIS – remote and speculative measures were not included in the formulation of the navigation-related or ES-related alternative plans.

- Alternatives with more significant adverse effects than the proposed actions need not be evaluated in an EIS – no attempts were made to identify "maximum adverse effects" plans which could be used for comparison with the reasonable navigation-related and ES-related plans.

- Alternatives with impacts that are indistinguishable from the proposed action need not be evaluated in an EIS – all of the navigation-related alternative plans, as well

as all of the ES-related plans, are distinguishable from each other relative to costs, benefits, environmental effects, and influence on ES.

10.3.3 Screening Process for Navigation-Related Plans

1. A screening process based on either preliminary economic evaluations or consistency with the definitions of WOPC or WPC was used for navigation-related measures. This process is described in Section 8 for WOPC and in Section 9 for WPC. As a result, some considered measures were eliminated for the plans addressing both conditions. For example, **Table 8.4** indicates that the following maintenance measures were eliminated from further consideration in the WOPC plan – full implementation of a miter gate quick changeout system for lock gate replacement, scheduled component replacements, major rehabilitation, and replacement-in-kind. However, it should be noted that even though all four of these measures were eliminated from the WOPC plan, they were included for consideration in the WPC plans. Further, **Table 8-5** lists two operational and low-cost structural measures that were eliminated from the WOPC plan; they are operational traffic scheduling and low-cost structural guide/guard wall extensions. Detailed economic and related policy information associated with the elimination of each of the measures listed in **Tables 8-4** and **8-2** is in the **Economics Appendix**.

2. Relative to the screening process applied to measures for potential inclusion in the WPC plans, **Table 9-1** indicates that two measures carried forward from Section 8 (full implementation of a miter gate quick changeout system for lock gate replacement, and replacement-in-kind) were eliminated from the WPC plans. However, the other two measures carried forward from Section 8 (scheduled component replacements and major rehabilitation) were included in the WPC plans. Regarding operational and low-cost structural measures, **Table 9-2** indicates that four measures were eliminated from the WPC plans; namely, operational traffic scheduling, congestion fees, traffic scheduling by the Corps, and low-cost structural guide/guard wall extensions. The first and last of these four measures had also been eliminated from the WOPC plan.

3. Regarding various lock modernization measures evaluated for the WPC plans in Section 9, **Table 9-6** indicates that four types of measures were eliminated from the WPC plans – they include (1) extensions less than 600 ft. for all existing auxiliary chambers with dimensions of 600 ft. by 110 ft.; (2) third locks at any of the 19 existing or authorized lock and dam projects; (3) lengths of new locks at Emsworth, Dashields and Montgomery (EDM) between 600 ft. and 1200 ft.; and (4) widths of new locks at EDM less than 110 ft. A fifth, the removal of any of the 19 locks and dams comprising the Ohio River mainstem navigation system, was not evaluated in this study. Again, detailed economic and related policy information associated with the elimination of each of the measures listed in **Tables 9-1**, **9-2**, and **9-6** is in the **Economics Appendix**.

10.3.4 Description of Components within the Navigation-Related Alternative Plans

1. Based on the screening process for navigation-related plans as described in Sections 8 and 9, as well as earlier information in this section, the included measures for four such plans can be identified. **Table 10-43** begins with a descriptive listing of the measures in the WOPC plan, also called the Reactive Maintenance Alternative (RMA). The WOPC plan includes three maintenance measures, four operational measures, and three low-cost structural measures.

2. **Table 10-43** includes a descriptive listing of the measures in the least comprehensive of the three WPC plans; the AMA. The AMA includes each of the measures from the RMA, as well as two new maintenance measures (lock gate replacement and scheduled component replacements). As a result, the AMA includes five maintenance measures, four operational measures, and three low-cost structural measures. Information related to applying routine and cyclical maintenance measures, along with the timing of lock gate replacements and scheduled component replacements is shown, as appropriate, for 16 of the current lock and dam projects in **Tables 10-15 through 10-31**. Specific application of the AMA to the Greenup and Myers projects was not done since these projects are subject to current authorized improvements; further, application of the AMA was not evaluated for locks and dams 52 and 53 because they will be replaced by the "under construction" Olmsted lock and dam project.

3. **Table 10-43** continues with a descriptive listing of the measures in the middle comprehensive of the three WPC plans; this plan is referred to as the Major Rehabilitation Alternative (MRA), which includes each of the measures in the AMA, as well as one new maintenance measure (major rehabilitation). As a result, the MRA includes a total of six maintenance measures, four operational measures, and three low-cost structural measures. As noted above, timing and locations associated with the application of these measures are shown, as appropriate, in **Tables 10-15 through 10-31**.

TABLE 10-43

Navigation-Related Measures in the WOPC Plan
And the WPC Alternatives

Navigation-Related Measures in the WOPC Plan – Reactive Maintenance Alternative
Maintenance Measures
Routine Maintenance – Small jobs such as painting, equipment lubrication, repair of equipment, landscaping, and repair of random minor component failures.
Cyclical Maintenance – Scheduled inspections and repairs to major components, including chamber dewatering.
Unscheduled Repairs – All unscheduled repairs of major components are repaired under emergency conditions.
▪ **Operational Measures**
N-up/N-Down Lockage Policy
Advanced Notice of Main Chamber Closures
Adjustment of Shipment Schedules by Industry

Helper Boats by Industry
▪ **Low-Cost Structural Measures**
Tow Haulage
Mooring Cells
Temporary Mooring Facilities During Main Chamber Closures
Navigation-Related Measures in the Least Comprehensive WPC Plan - Advanced Maintenance Alternative
Includes all Maintenance, Operational and Low-Cost Structural Measures listed above for WOPC, plus:
Maintenance Measures
Lock Gate Replacement – Only current capabilities are considered. No additional features are implemented during planning period.
Scheduled Component Replacements
Navigation-Related Measures in the Middle Comprehensive WPC Plan – Major Rehabilitation Alternative
Includes all Maintenance, Operational and Low-Cost Structural Measures listed above for WPC – Advanced Maintenance Alternative, plus:
Maintenance Measures
Major Rehabilitation – Repair, replacement, or reconstruction of major components costing at least $10.6 million for projects starting in FY 2006 (October 2005 – September 2006)
Navigation-Related Measures in the Most Comprehensive WPC Plan – Lock Modernization Alternative
Includes all Maintenance, Operational and Low-Cost Structural Measures listed above for WPC – Major Rehabilitation Alternative, plus:
Lock Modernization Measures
New 110' x 600' lock at Emsworth project
New 110' x 600' lock at Dashields project
New 110' x 600' lock, or possibly a new 110' x 1200' lock at Montgomery project

4. **Table 10-43** concludes with a descriptive listing of the measures in the most comprehensive of the three WPC plans. This plan is referred to as the Lock Modernization Alternative (LMA) and includes each of the measures in the MRA, as well as lock modernization measures for EDM. Extensions of 600 ft. were considered for four 600 ft. long auxiliary chambers downstream of the Montgomery project; however, none were economically justified. As a result, the LMA includes a total of six maintenance measures, three lock modernization measures, four operational measures, and three low-cost structural measures. As mentioned above, timing and locations associated with the application of the maintenance measures and lock modernization measures are shown, as appropriate, in **Tables 10-15 through 10-31**.

5. **Table 10-44** presents the projected initial year of three categories of site-specific projects, by existing project, in the three WPC alternatives (these tabulations were compiled from **Tables 10-15 to 10-31**). In addition, it should be noted that the timing of the site-specific projects are dependent on the navigation traffic scenario. Further, such projects will have different durations; e.g., advanced maintenance of selected components, depending upon the component, may require up to 2 years for completion.

Major rehabilitation projects can take up to 5 years, and new locks may extend to 7 years. Some observations related to the timing and site-specific economically justified projects listed in **Table 10-35** are as follows:

- The decade from 2010 to 2020 includes one new lock each at the Emsworth, Dashields, and Montgomery projects (2010 to 2012 depending on the navigation traffic scenarios). Major rehabilitations are projected for the Pike Island (2015 to 2016), Hannibal (2011 to 2012), Belleville (2017 to 2028), Racine (2019 to 2020), Meldahl (2010 to 2013), Markland (2010), Cannelton (2016 to 2017), Newburgh (2015 to 2025), and Myers (2011-2013) projects. Further, advanced maintenance, including scheduled replacements of selected components, is identified for the New Cumberland (2015), Pike Island (2015), Meldahl (2017), Markland (multiple replacements beginning in 2013 – see **Table 10-26**), McAlpine (2010 to 2030; includes multiple replacements – see **Table 10-27**), and Smithland (2013) projects.

- The decade from 2021 to 2030 also includes major rehabilitation efforts at Willow Island (2027 to 2028), and Byrd (2030 to 2045) projects. Advanced maintenance projects are also scheduled for the Markland and McAlpine projects during this decade.

- The four decades from 2031 to 2070 include possible major rehabilitation efforts at the Byrd and Markland (auxiliary chamber) projects, depending upon the navigation traffic scenario. Advanced maintenance projects are also listed for the Pike Island (2051 to 2069), Hannibal (2065), Racine (2048 to 2052), Meldahl (2063), and Markland (auxiliary chamber) projects, again depending upon traffic scenario.

6. The above tabulations illustrate that a major infrastructure program is required for the Ohio River mainstem navigation system in the time period from 2010 to 2030.

TABLE 10-44
Composite List of Site-Specific Projects[a] for the Navigation System on the Ohio River Mainstem (2010 to 2070)

Existing Lock and Dam	Initial Year		
	Advanced Maintenance Projects	Major Rehabilitation Projects	New Lock Projects
Emsworth			2010
Dashields			2010
Montgomery			2010
New Cumberland	2015		
Pike Island	2015 2068-2069	2015-2016 2043	
Hannibal	2065	2011-2012	

Willow Island		2027-2028	
Belleville		2017-2028	
Racine	2048-2052	2019	
Byrd		2030-2045	
Greenup[d]			
Meldahl	2017 2056, 2068	2010-2013	
Markland	2013-2046[b]	2010	
McAlpine	2010-2032[c]		
Cannelton		2016-2017	
Newburgh		2015-2025	
Myers[e]			
Smithland[f]	2010-2054		
Olmsted[g]			

[a] compiled from Tables 10-15 to 10-30
[b] see multiple listings in Table 10-26
[c] see multiple listings in Table 10-27
[d] Greenup is authorized and scheduled for auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).
[e] Myers is authorized and scheduled for auxiliary chamber extension by 2010 (includes replacement of gates and the electrical system).
[f] see multipole listings in Table 10-31
[g] Olmsted is currently under construction

10.3.5 Prioritization Process for Environmental Sustainability-Related Plans

1. As discussed in Section 8.8.1, a prioritization process was used to progressively group the 26 identified ES measures (see **Table 8-10**) according to their planning requirements, relative costs, and implementation complexity. The purpose of the prioritization was not to eliminate any measures; rather, it was to delineate groups of ES-related measures that could be formulated into ES alternative plans. The fundamental concept for the plans was that some measures could be implemented in the near term, while others would need more planning and greater funding levels. Further, some measures might require new authorizations for implementation. The characteristics of the resultant four groups are described as follows:

- Group A: 4 measures for which authority already exists and which involve minimal costs. These measures would involve minimal costs; increase awareness of key VECs, focus on impact prevention, and could be implemented relatively quickly.

- Group B: 10 measures for which authority already exists, but which would require some costs for planning and/or construction. These measures focus on key VECs and incorporate restoration and enhancement goals.

- Group C: 5 measures for which some authority already exists, but new authority may be needed for some opportunities. Planning and construction costs may be

relatively high. These measures generally encompass broad descriptions of opportunities that may need refinement, thus the focus tends toward broader-level environmental needs.

- Group D: 7 measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunities that may need refinement, thus the focus tends toward broader-level environmental needs.

2. **Table 10-45** lists the individual ES measures associated with each group (these measures are extracted from **Table 8-10**). Although there are descriptive tables in Sections 8 (**Table 8-6**) and 9 (**Table 9-10**) that address the potential beneficial and adverse effects of the measures in the four groups on five major VECs (water quality, fish, mussels, riparian resources, and recreation), it is stressed that no detailed analysis of the environmental benefits from the measures, or their anticipated costs for implementing the measures, was conducted within the ORMSS. Conducting such a study should be a high priority in the near term.

3. From a policy perspective consistent with the definitions of the Without Project and With Project Conditions in Sections 8 (WOPC) and 9 (WPC), the four groups of ES measures can be divided as follows:

- WOPC measures for ES – Groups A and B
- WPC measures for ES – add Groups C and D

On this basis, three ES-related alternative plans can be formulated as follows:

- ES-related Minimal Plan – includes Groups A and B measures
- ES-related Moderate Plan – includes Groups A, B, and C measures
- ES-related Maximum Plan – includes all four groups of measures

4. As noted above, the individual ES measures included in each plan are listed in **Table 10-45**.

10.3.6 Overall Comparisons of the Alternative Plans

1. As noted in Section 10.6.1 above, the Corps' Planning Guidance Notebook indicates that each alternative plan should be evaluated relative to their accomplishment of the study objectives, as well as in relation to four specified criteria – completeness, efficiency, effectiveness, and acceptability. For purposes herein, the overall comparisons will be separately considered for the four navigation-related plans and the three ES-related plans. This separation will facilitate the identification of an NED plan and an

NER plan. For this study, the National Ecosystem Restoration (NER) plan will be the optimum of the three ES-related plans. Therefore, the NER plan for the Ohio River mainstem will be referred to as the National Environmental Sustainability (NES) plan.

2. **Table 10-45** summarizes the overall comparisons of the four navigation-related alternative plans. As mentioned earlier, the plans are progressive from left to right. That is, the AMA includes the RMA; the MRA includes the AMA; and the LMA includes the MRA. The rows in **Table 10-45** reflect three groups of comparisons; namely, achievement of planning objectives, compliance with four planning criteria as specified in the Planning Guidance Notebook (ER 1105-2-100), and the extent of new authorizations needed. Definitions for the four planning criteria are included in the footnotes, along with definitions of the descriptive comparisons used within the table. The selected descriptive codes are based upon information contained in Sections 6, 8, and 9, as well as the earlier portions of this section.

Table 10-45
Overall Comparisons of the Features of the Navigation-Related Alternative Plans

Evaluation Factors	Navigation-Related Plan			
	WOPC (RMA)	WPC (AMA)	WPC (MRA)	WPC (LMA)
Planning Objectives				
(1) Ensuring future navigability				
• Provide appropriate maintenance measures to existing facilities	yes	yes	yes	yes
• Provide new, improved or replacement facilities (as economically justified)	no	yes	yes	yes
(2) Improving navigation efficiency				
• Schedule and execute maintenance	partial	yes	yes	yes
• Include low-cost structural options to maximize NED	yes yes	yes	yes	yes
(3) Enhancing ES				
• Minimize degradation of natural resources	no	partial yes	partial yes	yes
• Improve sustainability of resources in and along the Ohio River	no	no	no	no
Decision Criteria				
Completeness[a]	least best	third best	second best	best
Efficiency[b]	least best	third best	second best	best
Effectiveness[c]	least best	third best	second best	best
Acceptability[d]	least best	third best	second best	best
New Authorizations				

Evaluation Factors	Navigation-Related Plan			
	WOPC (RMA)	WPC (AMA)	WPC (MRA)	WPC (LMA)
Authorizations needed[e]	none	none	some	most

Definitions of factors

[a] Completeness = the extent to which the alternative plan provides and accounts for all necessary investment or other actions to ensure realization of the planning objectives, including actions by other Federal and non-Federal entities

[b] Efficiency = the extent to which an alternative plan is the most cost-effective means of achieving the objectives

[c] Effectiveness = the extent to which the alternative plan contributes to achieving the planning objectives

[d] Acceptability = the extent to which the alternative plan is acceptable in terms of applicable laws, regulations, and public policies

[e] Authorizations needed = new authorizations needed to accomplish the plan

Definitions of descriptive codes

yes = the plan satisfies the sub-objective statement

no = the plan does not satisfy the sub-objective statement

partial yes = the plan partially satisfies the sub-objective statement

best = relative to the four plans, this is the "best plan" for either satisfying the sub-objective or an individual decision criterion (completeness, efficiency, effectiveness, or acceptability)

second best = second best plan as per definition of best plan above

third best = third best plan as per definition of best plan above

least best = least best plan as per definition of best plan above

most = most new authorizations are needed to accomplish the plan

some = some new authorizations are needed to accomplish the plan

none = no new authorizations are needed to accomplish the plan

3. The following summary observations can be made based on the relative comparisons in **Table 10-45**:

- Relative to the planning objectives, the MRA and LMA both satisfy the two navigation-related planning objectives – ensuring future navigability and improving navigation efficiency. Neither plan satisfies the objective related to enhancing ES.

- Relative to the four decision criteria, the LMA is considered as the best plan for satisfying the completeness, efficiency, effectiveness, and acceptability specifications. The RMA is the least best in these comparisons.

- In relation to new authorizations, the LMA will require the most because it is the most all-inclusive and most comprehensive of the four plans.

Finally, based on the overall comparisons in **Table 10-34,** the following rank order from highest to lowest can be delineated for the four plans:

4 = best plan = LMA
3 = second best plan = MRA

2 = third best plan = AMA
1 = least best plan = RMA

Based on this rank order, the LMA could tentatively be identified as the NED plan.

4. **Table 10-46** summarizes the overall comparisons of the three ES-related alternative plans. As was the case with the navigation-related plans, the ES plans are also progressive from left to right. That is, the ES-related Minimal Plan includes Groups A and B measures; while the ES-related Moderate Plan includes Groups A, B, and C measures. The ES-related Maximum Plan includes all four groups of measures. As was the case for **Table 10-45**, **Table 10-46** also reflects three groups of comparisons. Further, the footnotes include definitions for the four planning criteria and descriptor word comparisons used in the table. The selected descriptive codes are based upon information contained in Sections 8 and 9.

TABLE 10-46
Overall Comparisons of the Features of the ES-Related Alternative Plans

Evaluation Factors	ES-Related Plan		
	Minimal (A, B)	Moderate (A, B, C)	Maximum (A, B, C, D)
Planning Objectives			
(1) Ensuring future navigability			
• Provide appropriate maintenance measures to existing facilities	no	no	no
• Provide new, improved or replacement facilities (as economically justified)	no	no	no
(2) Improving navigation efficiency			
• Schedule and execute maintenance	no	no	no
• Include low-cost structural options to maximize NED	no	no	no
(3) Enhancing ES			
• Minimize degradation of natural resources	partial yes	partial yes	partial yes
• Improve sustainability of resources in and along the Ohio River	partial yes	yes	yes
Decision Criteria			
Completeness[a]	least best	second best	best
Efficiency[b]	least best	best	second best (many unknowns)
Effectiveness[c]	least best	best	second best (many

Evaluation Factors	ES-Related Plan		
	Minimal (A, B)	Moderate (A, B, C)	Maximum (A, B, C, D)
			unknowns)
Acceptability[d]	least best	best	second best (many unknowns)
New Authorizations			
Authorizations needed[e]	none	some	most

Definitions of factors

[a] Completeness = the extent to which the alternative plan provides and accounts for all necessary investment or other actions to ensure realization of the planning objectives, including actions by other Federal and non-Federal entities

[b] Efficiency = the extent to which an alternative plan is the most cost-effective means of achieving the objectives

[c] Effectiveness = the extent to which the alternative plan contributes to achieving the planning objectives

[d] Acceptability = the extent to which the alternative plan is acceptable in terms of applicable laws, regulations, and public policies

[e] Authorizations needed = new authorizations needed to accomplish the plan

Definitions of descriptive codes

yes = the plan satisfies the sub-objective statement

no = the plan does not satisfy the sub-objective statement

partial yes = the plan partially satisfies the sub-objective statement

best = relative to the three plans, this is the "best plan" for either satisfying the sub-objective or an individual decision criterion (completeness, efficiency, effectiveness, or acceptability)

second best = second best plan as per definition of best plan above

least best = least best plan as per definition of best plan above

most = most new authorizations are needed to accomplish the plan

some = some new authorizations are needed to accomplish the plan

none = no new authorizations are needed to accomplish the plan

5. The following summary observations can be made based on the relative comparisons in **Table 10.46**:

- Relative to the planning objectives, none of the three ES-related plans satisfy the planning objectives related to ensuring future navigability and improving navigation efficiency. For the "enhancing ES" objective, all three plans would aid to some extent, in the sub-objective related to minimizing degradation of natural resources. For the "improve sustainability" sub-objective, the Moderate Plan and the Maximum Plan both receive a "yes" since they will both aid in improving resource sustainability.

- Relative to the four decision criteria, the Moderate Plan is considered as the "best plan" for satisfying the decision criteria. The comprehensiveness of the Maximum Plan is accompanied by several scientific, policy, funding and timing uncertainties that led to its designation as "second best". Further, the broad scale

of several actions (see Group D of **Table 8-9**) considered under the Maximum ES Plan also adds to the complexity and uncertainty of this option.

- In relation to required new authorizations, the most would be associated with the Maximum Plan, with some such authorizations also required for the Moderate Plan.

- Finally, based on the overall comparisons in **Table 10-46**, the following rank order from highest to the lowest plan, can be delineated as follows:

  3 = best plan = Moderate Plan
  2 = second best plan = Maximum Plan
  1 = least best plan = Minimal Plan

6. Based on this rank order, the ES-related Moderate Plan could tentatively be identified as the NES Plan.

10.3.7 Detailed Comparison of the Alternative Plans

1. In addition to the overall comparisons of the four navigation-related plans in Section 10.3.6, as well as such comparisons for the three ES-related plans, the Corps' Planning Guidance Notebook also infers that detailed comparisons should be accomplished. Specific comparative factors should be selected based on appropriate identified economic and ES metrics. Such metrics should be connected to the planning objectives of the specific study. As was the case in Section 10.3.6, the four navigation-related plans and three ES-related plans are subjected to separate detailed comparisons herein to facilitate the identification of a NED plan and a NES plan.

2. **Table 10-47** summarizes the detailed comparisons of the four navigation-related alternative plans. Again, the plans are progressive from left to right. That is, the AMA includes the RMA; the MRA includes the AMA; and the LMA includes the MRA. The rows in **Table 10-47** reflect seven economic metrics and five ES metrics. Summary descriptions of the metrics, and their units of expression, are contained in the footnotes.

Table 10-47
Detailed Comparisons of the Features
of the Navigation-Related Alternative Plans

Evaluation Factors	Navigation-Related Plan			
	WOPC (RMA)	WPC (AMA)	WPC (MRA)	WPC (LMA)
Economics Metrics[a]				
• Range of system benefits	$2252.8(CS)[b] - 2460.1(UBH)	$2365.8(CS) - 2584.4(UBH)	$2368.6(CS) - 2597.7(UBH)	$2400.6(CS) - 2693.4(UBH)
• System costs	$99.0(CS) - 100.2(MCS & UBH)	$100.0(UB) - 101.7(NAAQS)	$97.4(UB) - 98.8(NAAQS)	$118.0(CS) - 121.5(NAAQS)

• Net benefits	$2153.8(CS) - 2360.1(UBH)	$2265.0(CS) - 2484.1(UBH)	$2269.5(CS) - 2500.2(UBH)	$2282.6(CS) - 2574.9(UBH)
• Plan BCR	22.7(CS) - 24.6(UBH)	23.5(CS) - 25.8(UBH)	23.9(CS) - 26.7(UBH)	20.3(CS) - 22.7(UBH)
• Incremental system benefits over RMA	0	$95.1(CS) - 174.1(NAAQS)	$115.7(CS) - 181.9(NAAQS)	$147.8(CS) - 259.8(NAAQS)
• Incremental system costs over RMA	0	$0.2(UBH) - 2.8(CS)	($0.0) (CS) – (-2.6) (UBH)	$18.4(UBH) - 21.5(NAAQS)
• Incremental net benefits over RMA	0	$94.8(CS) - 172.4(NAAQS)	$115.7(CS) - 183.2(NAAQS)	$128.8(CS) - 238.3(NAAQS)
Environmental Sustainability Metrics				
• Effects indicator – eroded savings[c]	$75.8(CS) - 124.1(NAAQS)	$17.6(CS) - 74.4(MCS)	$17.6(CS) - 62.7(MCS)	$12.9(CS) - 23.6(UBH)
• Effects indicator – transit time differences (WOPC - WPC/LMA)[d]	NA[e]	NA	NA	15,500 (2015-2020); 33,500 (2030-2070); 1,725,000
• Effects indicator – HUs (NAVPAT) differences (WOPC - WPC/LMA)[f]	NA	NA	NA	See Note 1 below
• Localized direct and indirect effects on 6 key VECs[g]	See Table 10.36	See Table 10.36	See Table 10.36	See Table 10.36
• Influence on ES[h]	See Table 10.36	See Table 10.36	See Table 10.36	See Table 10.36

Descriptions of factors

[a] With the exception of the benefit cost ratio, BCR, a unitless metric, the remaining six economic metrics are average annual benefits or costs over the 2010 to 2070 study period; these annualized metrics are expressed in millions of dollars (FY03) at a discount rate of 5 1/8%. The data for the economic metrics are in Section 8 (WOPC) and the first portions of Section 10 (WPC).

[b] The letters in parenthesis refer to the five navigation traffic scenarios as follows: CS = Clear Skies, MCS = Modified Clear Skies, NAAQS = National Ambient Air Quality Standards Growth, UB = Utility Based, UBH = Utility-Based High

[c] The displayed metrics are in units of annual average eroded savings over the 2010 to 2070 study period; these annualized metrics are expressed in millions of dollars (FY03) at a discount rate of 5 1/8%. The data for these metrics are in Section 8 (WOPC) and the first portions of Section 10 (WPC).

[d] Differences in transit time within or through the navigation system are shown for equilibrium traffic for the WOPC and WPC/LMA plans, hence only the WPC/LMA column is used. The first two listed numbers represent annual reductions, in cumulative annual days, for two time periods; the final number is the cumulative transit days reduction to the 2070 end of the study period. Reductions refer to the difference in transit days between the WOPC and WPC conditions. From the viewpoint of both navigation efficiency and minimizing effects on aquatic resources, greater differences are more desirable.

[e] NA = the cell is not applicable for displaying comparative information for the factor

[f] HUs refers to habitat units associated with seven species/life stages analyzed by the NAVPAT model. HUs per se reflect both habitat quality and spatial size. Differences in HUs between the WOPC plan and the WPC/LMA plan were analyzed for all five traffic scenarios in 2010, 2040, and 2070. Further, such differences were determined for the WOPC plan from 2010 to 2070, and for the WPC/LMA plan for the same time period.

[g] Brief descriptions in Table 10-36 to summarize relative direct and indirect effects on water quality, fish, mussels, riparian resources, recreation, and health and safety. Detailed descriptions of effects are in Tables 8-8 (WOPC-RMA) and 9-12(WPC-AMA, MRA, and LMA).

[h] Brief descriptor words are used in Table 10.36 to summarize the influence of each plan on the overall ES of water quality, fish, mussels riparian resources, recreation, and health and safety, as appropriate. Detailed descriptions of the influences are in Sections 8.7.2 and 8.7.3 for the WOPC/RMA plan, and in Sections 9.7.1 and 9.7.2 for the three WPC plans.

Note 1: Minimal changes noted for WOPC minus WPC plans for 2010, 1040, and 2070. Some potential concerns noted for 2070 forecasts and for specific species/life stages at some lock and dam projects

3. The following summary observations can be made based on the relative comparisons in **Table 10-47:**

- The seven economic metrics can be divided into two groups. The first four are related to metrics for the four individual plans, and the latter three display incremental differences relative to the WOPC/RMA. Ranges of the metrics are included along with designators as to the traffic scenario that prompted the lowest and highest data within the range.

- Regarding the plan-related first four economic metrics, the ranges for system benefits and system costs generally increase from the RMA to the LMA plans. The LMA plan system costs are the highest of the four plans; as a result, the BCR range for the LMA plan is reduced to 20.46 to 22.56. The BCR ranges for the other three plans are from 23.40 to 27.07. The lowest BCRs for all four plans are associated with the Clear Skies scenario, while the highest are for the Utility-Based High scenario.

- Regarding the incremental benefits, costs, and net benefits, the LMA plan exhibits both the highest incremental benefits range ($84.6 million to $176.9 million) and the highest net benefits range ($66.2 million to $157.2 million). Again, the low side of both ranges is for the Clear Skies traffic scenario, and the high side is for the Utility-Based High scenario.

- Based upon the above observations relative to the seven economic metrics, the WPC/LMA plan represents the optimum choice as a navigation-related plan.

- The "eroded savings" effect indicator was described in Section 10.2.3.1. Ranges of the comparative data for each plan across the traffic scenarios are included in **Table 10-47**. For this indicator, lower "eroded savings" are reflective of lesser queuing in tailwater areas below locks, and also lesser negative effects on the tailwater habitats. For this indicator the WPC/LMA plan again reflects the optimum choice among the navigation-related plans.

- The transit time effects indicator is based on the differences in system transit days with the WOPC plan versus the WPC/LMA plan. As illustrated in **Table 10-35**, positive values for transit days are desirable because they represent system reductions in transit days between the WOPC/RMA plan and the WPC/LMA plan. **Table 10-47** indicates positive cumulative annual values for two time periods, and an overall cumulative value accrued to 2070. These displayed differences indicate that the WPC/LMA plan would be a better choice than the WOPC/RMA plan. Although not presented in **Table 10-47**, lesser positive differences would also occur for the WPC/MRA and WPC/AMA plans. Reductions in transit days are environmentally beneficial since less queuing in important tailwater habitat areas would occur. Accordingly, the WPC/LMA plan represents the optimum choice based on the transit time difference.

- Relative to the HU effects indicator, a summary discussion of the effects is in Section 10.2.3.6.3. The effects are based on differences between the WOPC/RMA plan and the WPC/LMA plan. In general, the large majority of the forecasted differences are less than the NAVPAT model's output variability threshold (plus or minus 3%); thus significant changes in HUs are not anticipated. However, further refinement of the model will improve its forecasting capabilities, and further evaluations of future HUs could be incorporated in a follow-on adaptive management program. Based upon the information in Section 10.3.7, and as included in **Table 10-47**, the WPC/LMA plan again represents the optimum choice among the four plans.

4. The final two listed factors in **Table 10-47** are summarized in **Table 10-48** and discussed as follows. To begin, it should be noted that construction of new locks at EDM requires permanent new impacts that are outside of the following summary discussion of the impacts resulting from maintenance of an existing infrastructure. Permanent new impacts include the loss of aquatic habitat within the 'footprint' of each new 600'x110' lock (approximately 2 acres), new approach dredging and maintenance, and changes to flow patterns resulting from the new lock configuration. While the ES tradeoffs of these new impacts are discussed in a qualitative fashion within the context of this Programmatic EIS, more detailed and quantitative assessment of such impacts should be addressed in project specific assessments when such projects are recommended for feasibility studies. As noted above, **Table 10-48** summarizes the ES tradeoffs of the navigation-related alternative plans with these permanent new impacts excluded.

Table 10-48
Summary of Effects of Navigation-Related Plans on ES

RMA	Individual	Impacts occur due to unscheduled repair events; impacts are temporary/local and proportional to duration/complexity of repairs. Impacts reduced somewhat by N-up/N-down & related operational & low-cost structural measures.
	Cumulative	Increasing frequency and duration of impacts as system ages.

AMA	Individual	Repair events approximately equivalent to RMA repairs, but queuing impacts somewhat reduced by scheduling vs. 'fix-as-fail'.
	Cumulative	Increasing frequency and duration of impacts as system ages, reduced by incremental effects of scheduling. Some postponement of negative ES effects of queuing.
MRA	Individual	Repair event impacts are bigger, longer duration than AMA.
	Cumulative	Reduced frequency of impacts due to consolidation of events, longer recovery between events. Additional postponement of negative ES effects vs. AMA includes reduced construction impacts.
LMA	Individual	Project impacts similar to big MRA project, longer duration.
	Cumulative	Long term benefits of increased capacity and renovated condition: repair induced queuing approaches zero and frequency of repairs declines. Notes: reduced construction related impacts due to new condition of new locks at EDM and subsequent reduction in frequency of repair events. Construction induced queuing approaches zero due to equivalent capacity of the older lock.

5. Individual impacts in **Table 10-48** refer to a single repair event that represents the most important activity for each alternative. These events are:

RMA – emergency repair in response to component failure
AMA – scheduled repair prior to expected failure of a component
MRA – scheduled repair of multiple components
LMA – construction of a new 600' x 110' lock at Emsworth, Dashields, or Montgomery

6. Cumulative impacts in this context refer to the long term effects of implementing each alternative plan as it applies to a specific lock and dam project. A follow up step for cumulative assessment would aggregate cumulative project specific impacts for the total system of 19 lock and dam projects.

7. Impacts can be subdivided into two principal categories: construction impacts and construction induced queuing. Construction impacts are directly proportional to the scope and duration of the overall project, while queuing impacts are directly proportional to the duration of main chamber lock closures that occur during the construction.

8. The following represent a rank ordering of the individual and cumulative effects of the three WPC plans:

AMA Individual impacts
-construction related AMA=RMA
-queuing AMA<RMA

AMA Cumulative impacts	
-construction related	AMA=RMA
-queuing	AMA<RMA
MRA Individual impacts	
-construction related	MRA>AMA=RMA
-queuing	MRA>AMA<RMA
MRA Cumulative impacts	
-construction related	MRA<AMA=RMA
-queuing	MRA<AMA<RMA
LMA Individual impacts	
-construction related	LMA>MRA>AMA=RMA
-queuing	LMA>MRA>AMA<RMA
LMA Cumulative impacts	
-construction related	LMA<MRA<AMA=RMA
-queuing	LMA<MRA<AMA<RMA

9. To summarize the above rank ordering, if the WPC/LMA plan is selected, the individual direct and indirect effects will be greater than the other two WPC plans, with the difference primarily related to construction effects for locks at EDM. However, from a cumulative effects perspective, the LMA plan would result in lesser effects than the other two plans. Further, the lesser cumulative effects would be a positive contribution to the ES of the six key VECs (water quality, fish, mussels, riparian resources, recreation, and health and safety).

10. Finally, based on the detailed comparisons in **Tables 10-36** and **10-37**, and more extensive comparative information in Section 8 (WOPC), Section 9 (WPC), and earlier portions of Section 10 (WPC), the following rank order from the highest to the lowest plan, can be delineated for the four plans as follows:

4 = best plan = LMA
3 = second best plan = MRA
2 = third best plan = AMA
1 = least best plan = RMA

This rank order confirms the selection of the LMA as the NED plan. This same finding occurred in Section 10.3.6 for the overall comparisons.

11. **Table 10-49** summarizes the detailed comparisons of the three ES-related alternative plans. The ES plans are progressive from left to right; that is, the Minimal Plan includes the Groups A and B measures, the Moderate Plan includes the Groups A, B, and C measures, etc. The comparative information in **Table 10-49** is entirely based on the use of descriptive codes, which are defined in the explanatory notes. This approach

the use of descriptive codes, which are defined in the explanatory notes. This approach was necessary since neither a detailed analysis of the costs of the three plans, nor their environmental benefits, effects, and specific influences on ES, has been conducted. Nevertheless, the following summary observations can be made relative to the comparisons in **Table 10-49**:

- Relative to the economics-related metrics, the Moderate Plan is anticipated to be the best choice at this time. While the Maximum Plan has the potential to be the best ES-related plan, there are unknowns as to the effectiveness and costs of the Group D measures.

- Relative to the ES metrics, the Moderate Plan is anticipated to be the best choice at this time. Unknowns and uncertainties are still associated with the Maximum Plan.

Based on the above information, the rank order of the three ES-related plans are as follows:

3 = best plan = Moderate Plan
2 = second best plan = Maximum Plan
1 = least best plan = Minimal Plan

Based on this rank order the Moderate Plan could tentatively be identified as the NES Plan. This same finding occurred in Section 10.3.6 for the overall comparisons.

10.3.8 The Combined NED/NES Plan

Based on the overall comparisons in Section 10.3.6, and the detailed comparisons in Section 10.3.7, the combined NED/NES plan is as follows in **Table 10-49**: NED (WPC/LMA Plan) and NES (Moderate ES Plan).

Table 10-49
Detailed Comparisons of the Features of the ES-Related Alternative Plans

Evaluation Factors	ES-Related Plan		
	Minimal (A, B)	Moderate (A, B, C)	Maximum (A, B, C, D)
Economics-Related Metrics[a]			
• Plan environmental outputs (benefits)[b]	Minimal	Moderate	Maximum
• Plan costs	Minimal	Moderate	Maximum
• Plan net benefits	Minimal	Moderate	Maximum (but has unknowns and uncertainties)
• Plan Justified?	>Yes - lowest	>Yes - optimal	>Yes but has unknowns and

	outputs	outputs	uncertainties
• Incremental environmental outputs (benefits) relative to Minimal Plan	0	Positive	Positive
• Incremental costs relative to Minimal Plan	0	Greater	Greater
• Incremental net benefits relative to Minimal Plan	0	Positive	None Assigned
Environmental Sustainability Metrics[c]			
• Effects indicator-eroded savings[d]	NA	NA	NA
• Effects indicator-transit days[e]	NA	NA	NA
• Effects indicator-HUs (NAVPAT)[f]	NA	NA	NA
• Localized direct and indirect effects on 6 key VECs[g]	Minimal	Moderate	Maximum
• Influence on ES	Positive	More Positive	Most Positive

Definitions of factors

[a] With the exception of environmental outputs and BCR, the listed metrics would normally be expressed in similar units as those displayed in Table 10-35. However, since a detailed analysis of the economic parameters for the ES-related plans was not conducted, descriptive codes are used in Table 10-37. Information related to the measures included in Groups A, B, C, and D comprising the plans is in Sections 8.0 (WOPC) and 9.0 (WPC).

[b] Environmental outputs (or benefits) would typically be expressed in Habitat Units, quality improvements, or by other means. A detailed study to quantify the anticipated outputs has not been accomplished, thus descriptor codes are used in Table 10.37.

[c] The environmental sustainability of six key resources (water quality, fish, mussels, riparian resources, recreation, and health and safety) represents the focus of the three ES-related plans. The first four listed factors potentially contribute to ES, and the fifth factor represents a composite consideration of the first four.

[d, e, f, g] See definitions in Table 10.35.

Definitions of Descriptive Codes

Minimal = minimal (or least) metric in terms of the three ES-related plans and the related factor

Moderate = a mid-scale value in terms of the three ES-related plans and the related factor

Maximum = maximum (or highest) metric in terms of the three ES-related plans and the related factor

Positive = better than the Minimal Plan in relation to environmental outputs, net benefits, or influence on ES

None Assigned = no descriptor code used due to unknowns and uncertainties associated with the incremental comparisons

Greater = the costs for the Moderate Plan are greater than the costs for the Minimal Plan

NA = not applicable relative to the ES-related plan and the factor

More Positive = better than the Minimal Plan in relation to influence on ES

Most Positive = for the three ES-related plans, has the greatest potential for influencing ES

10.4 PREFERRED PLAN

The preferred plan includes all features of the best navigation (NED Plan) and environmental sustainability (NES Plan) investment plans as described in Sections 10.1 and 10.2. This combined plan maximizes the sum of net economic and environmental

benefits. The focus on planning and budgeting for low cost projects or site specific studies will be based on the combined plan. These actions will be spelled out as recommendations in Section 12.

10.4.1 Mitigation

1. A comprehensive investigation was conducted to determine mitigation opportunities and authorities available to the Corps. That discussion can be found at 8.5.2.1 of the SIP/PEIS. It must be understood that this document is programmatic in nature and does not seek authorization for any specific projects. Instead, it provides a roadmap for the most efficient modernization strategy to keep the navigation system functioning for the next 60 years and identifies types of ecosystem sustainability improvement needs. With the aid of this report, the Corps will develop feasibility level plans for each major recommendation that will identify the site specific plan that is most economically justified and environmentally beneficial. It is at this level that environmental impacts are best understood and site specific mitigation is best designed.

2. There are commitments the Corps will make toward mitigating systemic environmental impacts. Foremost of these, the Corps will adopt sustainability-focused mitigation measures as identified in the SIP/PEIS for its future actions. While potential measures identified in mitigation plans have typically focused on replacement-in-kind for anticipated adverse effects of planned projects, plans for future mitigation could include measures directed toward enhancing the environmental sustainability of affected resources and ecosystems. Such measures would be perceived as "sustainability-focused mitigation measures".

3. The Corps recognizes that actions it has taken in the past, prior to enactment of the National Environmental Policy Act, have had and continue to have profound impacts on certain environmental resources associated with the river, most notably mussels and lithophilic fishes. These adverse effects are a result of the navigation dams that have inundated and facilitated siltation of extensive reaches of formerly clean gravel or rubble substrate. Although impacts from the presence of the navigation projects will continue, several types of measures were identified that would improve conditions for aquatic and riparian resources. In regard to improving stewardship of Ohio River environmental resources, at the invitation of the Fish and Wildlife Service an annual meeting will be held between the Lakes and Rivers Division and District Commanders of the Corps and the Regional Directors of the USFWS Regional Offices with jurisdiction over the Ohio River to discuss where the agencies could become better stewards of the environment and participate, within our authorities, in making the river more sustainable.

The Corps of Engineers does not have an authority that would allow compensatory mitigation for impacts of past actions at full Federal expense. For ecosystem restoration where a Corps project caused or contributed to the degradation, Congress authorized Section 1135 of WRDA 1986, as amended, for the Federal government to provide a greater share of project costs than under other ecosystem

restoration authorities. Section 1135 is cost shared at 75% Federal and 25% non-Federal, whereas most other ecosystem restoration authorities are cost shared at 65% Federal and 35% non-Federal. Section 1135 has a Federal funding limit of $5,000,000 per project. Therefore it could not be used on large scale efforts to correct problems caused by existing projects. Section 8.5.2.1., paragraph 7. describes another authority, Section 216 of the River and Harbor and Flood Control Act of 1970 that could be used for large scale modification of projects. Section 216 projects require cost sharing with a non-Federal sponsor for feasibility study costs and project implementation.

4. The Corps recommended plan in the SIP/PEIS is the first step toward mitigating (i.e., minimizing) for traffic impacts. The areas of the river most subjected to navigation related impacts are the downstream approaches to the lock chambers where most of the remaining riverine habitat exists. By increasing reliability of the existing chambers (and constructing new chambers in the upper river), the time it takes to move traffic through this stretch of river will be reduced greatly. Transit Days are the days it takes to move one tow from point of origin to its destination. By implementing reliability improvements, we estimate that Transit Days will be reduced by 1.5 million over the study period. Since interpool transit rates will not change due to recommended improvements, the reductions will all be accounted for at the locks. Those days should be equally divided between up-bound and down-bound, therefore, there should be 750,000 less Transit Days, and concomitant impacts, in the lower approaches.

5. To address more systemic issues related to the navigation system, the Corps will incorporate several environmental components into future site specific studies that this report recommends:

a. Evaluation and, if feasible, implementation of fish passage strategies at each lock and dam along the Mainstem during studies for lock modernization and major rehabilitation.

b. Continuance and expansion, as needed, of the Interagency Working Group to participate in and to review and comment on studies as they progress.

c. Identification, description and quantification of riverine habitat within the individual project's area of influence.

d. Incorporatation of sustainability planning within each individual project's area of influence.

e. Development of a National Environmental Restoration (NER) Plan that will become part of the Combined NED/NER Plan for authorization of each site specific project. As required for navigation investments, however, all separable restoration costs will require a cost sharing partner.

SECTION 11
COORDINATION AND COMMENTS ON DRAFT REPORT

Public review of the May 2006 Draft System Investment Plan/Programmatic Environmental Impact Statement (SIP/PEIS) Main Report and Economic, Engineering, Environmental, and Communications Appendices occurred during the period May 26 – July 25, 2006. The Louisville District sent copies of the main report and appendices to various state, Federal, and local agencies – in partial fulfillment of the requirements of the National Environmental Policy Act (NEPA) - either in hard copy or Adobe Acrobat format on CDROM-disk. Copies were also sent to individuals who had previously indicated an interest in the study. **Table 11-1** lists all agencies receiving the report either in hard copy or in CDROM-disk at the beginning of the public review period.

The report was also sent to libraries in 13 major population centers along the Ohio River. In addition, over 3000 copies of a "Notice of Availability of the draft SIP/PEIS" were mailed at the same time. (A copy of the information contained in this mailing is shown in Exhibit 1.) This larger distribution included Federal, State and local agencies and government officials; transportation groups; navigation interests; environmental groups that have been active in navigation issues; U.S. Senators and Congressmen; libraries and news media in the Ohio Valley; and individuals who previously indicated an interest in Ohio River navigation.

Following distribution of the Notice, copies of the report on CDROM-disk were distributed to the general public on request. Digital versions of these documents were also available for download to Personal Computers via the Internet from the Louisville District public Internet site. The official review period comprised 60 days.

Table 11-1
Agencies and Organizations Receiving Report
at Beginning of Review Period

Illinois Department of Natural Resources, Springfield
Indiana Department of Natural Resources, Indianapolis
Ohio Department of Natural Resources, Hebron
Ohio River Sanitary Commission, Cincinnati
Pennsylvania Fish and Boat Commission, Bellefonte
U.S. Environmental Protection Agency, Region 5, Chicago, Illinois
Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky
U.S. Environmental Protection Agency, Region 4, Atlanta, Georgia
U.S. Environmental Protection Agency, Region 3, Philadelphia, Pennsylvania
U.S. Geologic Service, La Crosse, Wisconsin
U.S. Fish and Wildlife Service, Region 3, Fort Snelling, MN
U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia
U.S. Fish and Wildlife Service, Region 5, Hadley, Massachusetts
U.S. Fish and Wildlife Service, Frankfort, Kentucky
U.S. Fish and Wildlife Service, Marion, Illinois
U.S. Fish and Wildlife Service, Cartersville Fisheries Office, Marion, Illinois
U.S. Fish and Wildlife Service, Bloomington, Indiana
U.S. Fish and Wildlife Service, Reynoldsburg, Ohio
U.S. Fish and Wildlife Service, Elkins, West Virginia
U.S. Fish and Wildlife Service, Ohio River Islands, Parkersburg, West Virginia
The Nature Conservancy, Dublin, Ohio
Ohio River Foundation, Cincinnati, Ohio
Southern Illinois University, Carbondale, Illinois

Public meetings were held in Monaca, PA (just outside Pittsburgh), Marietta, OH, Huntington, WV, Metropolis, IL, Evansville, IN, and Covington, KY. The meetings were announced in four ways:

- All meetings were announced in the Notice of Availability of the draft SIP/PEIS described above.

- The Huntington, Louisville and Pittsburgh District Public Affair's offices issued news releases to the news media organizations in their respective Districts. (A copy of the Pittsburgh District's news release is included as Figure 11-2

- ***Federal Register*** Notice dated May 26, 2006 (Volume 71, Number 102) {Page 30391 – 30393).

- Meeting information and the text of the "Notice of Availability" of the report were available via computer on the Louisville District public Internet site, with links to this information placed on the Huntington and Pittsburgh District public Internet sites.

There were four ways that formal comments could be submitted: statement at any of the public meetings, letter, e-mail, or by phone. All comments were considered in preparation of this final draft. Comments were received from the following agencies and individuals:

1. R. Mike Morton, area resident
2. Irving Materials
3. Lyndon LaRouche Political Action Committee
4. Dave Clark, Paducah Power
5. Douglas Hess, Jr., Clearchannel
6. Rob Webb, Crounse Corp.
7. Anthony Davis, Louisville District, Corps of Engineers
8. Kentucky Department of Fish & Wildlife Resources, Commerce Cabinet
9. Pennsylvania Environmental Council
10. Ohio River Foundation
11. Eric Hollins, area resident
12. Riverfields, Inc.
13. U. S. Department of the Interior
14. Waterways Council, Inc.
15. Pennsylvania Fish and Boat Commission
16. Illinois Department of Natural Resources
17. U.S. Environmental Protection Agency, Region 5
18. Western Pennsylvania Conservancy
19. Indiana Department of Natural Resources
20. Port of Pittsburgh Commission
21. Southwestern Pennsylvania Planning Commission
22. Ohio Department of Natural Resources, Division of Wildlife

23. Claire Rieger, area resident
24. Unidentified Speakers at Public Meetings
25. LaRouche Youth Movement
26. Evansville, Indiana Port Authority Board
27. Inland Marina, Evansville
28. Bob Dieg, area resident
29. Evansville Marine Service
30. Moser Crushed Stone
31. Nick Damosko, area resident
32. Rick Pope, area resident
33. Russell Swankey, area resident
34. Wayne Lithow, area resident

All comments are either reprinted or summarized and Corps responses are provided in **Table 11.2**, along with the report section if any that was modified to accommodate the response. The number before the dash in each comment number indicates the commenter noted above.

TABLE 11-2
Comments on Draft Report And Responses

Comment #	Comment	Response	Revised Section
1-1	Disappointed at lack of discussion of environmental restoration, ecological restoration and recreational access improvements at the public meeting. What is status of advertised restoration of resources mentioned in "Ohio River, Future Navigation and Environmental Improvements" brochures?	The Corps shares your concern about the importance of improving ecological and recreational activities on the river. We spent a great deal of time reviewing these and other resources to better understand if they are sustainable or not. The Corps has authorities that allow us to address ecological and recreational issues and stand ready to use them if a suitable non-federal cost sharing partner steps forward. Just as navigation improvements are cost shared with the navigation industry, ecological and recreational improvement must be also. Until then, we will do what we can to address your concerns under good environmental design and mitigation for site specific features.	None
2-1	Supports a schedule of much needed repairs and replacements (not reactionary) to structures well into, at, or beyond their projected service life.	Support for study recommendations is noted and appreciated.	None
3-1	Supports the proposed Lock Modernization Alternative and construction needs at Emsworth, Dashields, and Montgomery L/Ds.	Support for study recommendations is noted and appreciated.	None
4-1	Nothing mentioned in Executive Summary about needs at Smithland, is it because it's new?	Smithland is relatively new, less than 40 years old and has twin 1200' long chambers. Therefore it is a low priority. Projected maintenance needs at Smithland are listed in Section 10, Table 10-31.	None
5-1	Disappointed in advertising public meeting in Marietta, Ohio.	We will work to improve our methods for notifying the public about upcoming meetings.	None

Comment #	Comment	Response	Revised Section
6-1	Would ton miles be a more accurate indicator of growth on the Ohio River?	Perhaps, but not necessarily. Corps analysis to estimate benefits from an improved inland navigation system is guided by Engineering Regulation (ER) 1105-2-100. The regulation defines National Economic Development (NED) benefits as cost reduction, shift of mode, shift of origin or destination, or a new movement and identifies the total tonnage that could benefit from using the waterway. The regulation directs us to cost navigation movements on a per ton basis. All of our transportation rate analyses, conducted by transportation specialists at the Tennessee Valley Authority (TVA), are performed on a per ton basis in accordance with ER 1105-2-100. However, we do use ton-mile measures. Ton-miles measure freight when we extrapolate rate data to the population of unsampled movements. Also, ton-miles are used as a metric in the annual Corps budget process to prioritize different navigable waterways and channels.	None
7-1	Observations that maintenance backlogs continue to grow and that failure of a navigation structure would create logistical problems for shippers.	A desired outcome of the SIP is the development of maintenance policies that reduce and eventually eliminate these backlogs. Of course, our ability to accomplish this will be subject to future funding levels for Operations and Maintenance.	None

Comment #	Comment	Response	Revised Section
8-1	Adaptive Management: Resource agency involvement should be a critical component of an adaptive management plan promoted in the Ohio River Mainstem System Study. Stakeholder involvement with each future project development should include individual state resource agencies.	Section 13.10 of the CEA report states that developing and implementing an adaptive management program for the Ohio River system could occur over time through the efforts of many stakeholders, but would be unlikely to occur in a focused way without 1) authorization of an agency to initiate a program, 2) formation of a broadly representative stakeholder group (including state resource agencies), and 3) funding over a long term.	None
8-2	Fish passage: The ORMSS should consider the potential need to address fish passage and opportunities. Fish passage should be considered in the context of the entire river. Individual projects should seek to implement fish passage components to meet identified needs.	Concur. Fish Passage has been identified as a system mitigation feature that will be evaluated at the site specific level.	10.4.1
8-3	Ecosystem Funding: Funding should be programmed for the selection and implementation of ecosystem restoration projects. Funding for implementation is lacking. Existing programs like Section 206 and 1135 do not effectively meet ecosystem needs. Matching requirements for these two programs are not attractive to sponsors. Where Ohio River ecosystem grants have been available, there have been funds for planning stages but not for implementation. As a result, Section 206 or 1135 projects are not cost effective or are not attractive to state wildlife agencies because of inadequate funding for project completion.	Current law and Corps policy requires cost sharing with a non-federal sponsor for ecosystem restoration projects. If a non-federal partner is identified, the Corps now has the authority to develop an ecosystem restoration plan that would become part of the combined plan and be authorized along with each site specific navigation project. The Corps is not authorized to administer any grants programs for implementing ecosystem restoration.	None
8-4	Ecosystem restoration should be fully funded concurrently with future projects on the river to achieve sustainability. Using ecosystem grants that require matching contributions from state or organizations should not be a required source of funding.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections

Comment #	Comment	Response	Revised Section
8-5	Ecosystem projects should be fully funded without cost share requirements	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections
8-6	A formal lead or team should be created to identify and promote the development of ecosystem restoration projects.	This will be decided during the implementation of the PIP should the Ecosystem Restoration Program receive funding for implementation.	None
8-7	There should be adequate funding to complete ecosystem restoration project implementation, not just preliminary planning.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections
8-8	Mitigation through Section 10/404 should be included as potential sources of matching non-federal funds when opportunities exist.	Using mitigation funds under the Sections 10/404 or any other type of mitigation as the non-federal cost share is prohibited by Corps Regulation.	None
8-9	Watershed based perspective should be given to matching funds requirements. Projects with Ohio River benefits but which may not be physically connected to a specific ecosystem project should be considered as a viable source of matching funds.	The program is currently limited to the Ohio River mainstem and its floodplain. Congress would have to modify the authority to extend the program into the watershed.	None
8-10	Funding should be added to individual Corps projects in the future as a potential means to implement ecosystem restoration projects.	The Corps' policies do not allow implementation of ecosystem restoration at 100% federal expense. Where compensatory mitigation is required for project impacts, such restoration is a project feature and is cost shared with the inland navigation trust fund for navigation projects.	None

Comment #	Comment	Response	Revised Section
8-11	Individual and/or competitive grants could be developed for implementation of individual ecosystem projects.	A list of federal conservation grants available to states and local governments and NGOs has been added to Section 8.5.4. The Corps does not currently have an authorized conservation grant program. It is unknown which, if any, of these could be used as a non-federal share of a cost shared ecosystem restoration project.	8.5.4
8-12	Floodplains-Bottomland Forest, Wetlands, and Riparian Corridor: Emphasis on restoring floodplains, wetlands, and riparian corridors should be prioritized with an emphasis on building upon existing conservation lands and maximizing opportunities. There are several identified opportunities along the Ohio River which would serve as viable restoration projects.	Floodplains, Bottomland Forests, wetlands, and riparian corridors were all identified for restoration efforts under the Ohio River Ecosystem Restoration Program. Aquatic habitat was also identified as targets for restoration. The sustainability needs analysis conducted for the ORMSS SIP/PEIS also included the need for action in these types of habitat.	None
8-13	We specifically highlight the need for enhancing areas with some existing free-flow conditions, restoring connectivity to tributary systems or embayment habitat, and restoring adjacent wetlands as part of the sustainability model. Several ecosystem projects in these areas have been identified previously but remain unfunded at the same time that commercial projects are being constructed.	Restoration of connectivity, both laterally and longitudinally were determined to be high priority needs in the sustainability analysis. Ecosystem restoration projects to address this need could be constructed but require cost sharing partners to proceed.	None
8-14	We specifically highlight the need for enhancing areas with some existing free-flow conditions, restoring connectivity to tributary systems or embayment habitat, and restoring adjacent wetlands as part of the sustainability model. Several ecosystem projects in these areas have been identified previously but remain unfunded at the same time that commercial projects are being constructed.	Restoration of connectivity, both laterally and longitudinally were determined to be high priority needs in the sustainability analysis. Ecosystem restoration projects to address this need could be constructed but require cost sharing partners to proceed.	None

Comment #	Comment	Response	Revised Section
8-14	It is appropriate to consider off-setting the cumulative effects to fish and wildlife through supplemental stocking and habitat restoration methods. In light of identified cumulative effects and the difficulty in getting habitat restoration implemented, it is appropriate to include supplemental fish and wildlife stocking as a reasonable and achievable option for addressing sustainability. We recommend that the Corps consider funding supplementing rearing or stocking efforts as a potential ecosystem restoration project. Fish or mussel stocking programs are on-going and might be used to supplement ecological restoration projects or to supplement populations in existing habitat.	Corps of Engineers Ecosystem Restoration efforts emphasize improving ecosystem function (in areas degraded by human activities) to a more natural condition. Supplemental stocking would not be included under ecosystem restoration, although there may be situations where reestablishment of extirpated species or communities could be considered following habitat restoration.	None
8-15	The Corps should work with stakeholders in a comprehensive fashion. For example, in some cases the Corps has not been receptive to coupling Section 10/404 mitigation to ecosystem projects, even in planning phases and when funding was entirely separated. This is counter-productive to achieving a desirable end result and ignores long-term and comprehensive ecosystem needs. The Corps should work under a comprehensive approach that is inclusive of watershed interests.	Using mitigation funds under the Sections 10/404 or any other type of mitigation as the non-federal cost share is prohibited by Corps Regulation. Such use would amount to"double counting." The Corps' Environmental Operating Principles require the agency strive for Environmental Sustainability and to respect the views of others. To be consistent with these principles, the Corps is seeking ways to develop a comprehensive approach to the way we do business on the river.	None
9-1	The Council supports the comprehensive study and plan for navigational improvements, particularly upgrades to Emsworth, Dashields and Montgomery Locks and Dams.	Noted.	None
9-2	It is crucial to conduct the navigational improvements while at the same time implementing ecological restoration efforts along the Ohio River corridor.	If a non-federal partner is identified, The Corps now has the authority to develop a National Environmental Restoration (NER) Plan that would become part of the Combined NED/NER Plan and be authorized along with the each site specific navigation project.	None

Comment #	Comment	Response	Revised Section
9-3	Efforts to maintain and restore riparian areas in the upper river will aid in abating flooding and preventing pollutant loading downstream. In order to accomplish this, the Council recommends the Corps obtain funding for Ohio River Ecosystem Restoration Program authorized by WRDA 2000.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections
9-4	Pursue planning and implementation of measures to improve environmental sustainability, including all reasonable and prudent measures identified in the ESA Section 7 consultation.	Noted.	None
9-5	Initiate preparation of the Program Implementation Plan for the Ohio River Ecosystem Restoration Program.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections
10-1	Disappointed that study recommendations do not include mitigation at the locks and dams to improve the ecology of the river. As detailed in section 8.5.2, legal authority exists for the Corps to institute mitigation measures now. These measures do not require funding under the authorized Ohio River Ecosystem Restoration Program, for example, fish passage.	Mitigation has been added to the final report under section 10.4.1.	10.4.1
10-2	It is not the intent or design of the Ohio River Ecosystem Restoration Program to fund mitigation projects. For the Corps to suggest otherwise would be an abrogation of its legal responsibility to mitigate for impacts caused by any of its projects or operations.	The Ohio River Ecosystem Restoration Program was authorized to restore habitat along the mainstem. It was not intended to fund mitigation.	None
10-3	By its failure to recommend what mitigation actions should be taken, the Corps fails to understand that in an attempt to avoid it legal responsibilities it will be undermining the efforts of thousands of Ohio River valley citizens.	Mitigation has been added to the final report under section 10.4.1.	10.4.1

Comment #	Comment	Response	Revised Section
10-4	Itemize the benefits in Table 2 in Executive Summary (ES). What do the costs in Table 2 represent? How much of the savings is subsidies?	The benefits in Table 2 are the transportation rate savings associated with system equilibrium traffic relative to least cost all-overland (alternative) routing. This also is in compliance with ER 1105-2-100. The costs represent a base-level estimate of federal expenditure on the operation, maintenance and repair of the mainstem to provide a minimum level of service. This federal expenditure could be conceived as a subsidy to the shipping public that utilizes the Ohio River mainstem much the same way that commercial trucking benefits from federally funded highway projects and railroads benefit from free lands and rights-of-ways.	None
10-5	Same questions for Table 4 of ES as Table 2.	Incremental benefits are the additional transportation rate savings for with-project equilibrium traffic relative to without-project equilibrium traffic. Most of this benefit is derived from cost reduction and shift-of-mode associated with a more efficient and reliable navigation system. The incremental costs are the additional federal and waterway trust fund dollars that buy the more efficient, reliable navigation system. Incremental net benefits are the difference in these two and the benefit cost ratio is simply the incremental benefit to incremental cost ratio. Total federal/trust fund costs range around $118 m per year for each of the next 60-years.	None

Comment #	Comment	Response	Revised Section
10-6	Implications of Assumption #4 on benefits, modeled or actual? If modeled, are they such when operating at full capacity? Why use full capacity for benefits when, as shown in Figure 6-2, locks are operating at less than capacity?	Assumption 4 means the tributary locks are modeled under normal operation which includes cyclical maintenance and random minor closures. We do not include reliability-based closures for the tributary locks; however, they are still capacity constrained by cyclical and random minor closures. The ORMSS SIP analysis limited lock reliability to the Ohio River mainstem projects.	None
10-7	What are "Reasonable and Prudent Measures"?	As a matter of policy, the USFWS requires all ESA consultations to have an Incidental Take Statement that specifies the amount and extent of unintentional take (to harm or harass) that will not jeopardize the continued existence of a listed species. The Incidental Take Statement will also include any Reasonable and Prudent Measures along with the terms and conditions to implement the measures that USFWS consider necessary to minimize impact to listed species. The Reasonable and Prudent Measures and the terms and conditions are nondiscretionary.	None
10-8	What is the Ohio River Basin Study? Why is the Corps the best choice to do it?	As stated in the Study Recommendation in Section 12, the Ohio River Basin Comprehensive Study will assess water resource opportunities throughout the basin in collaboration with other interests. Planning efforts will include identification and evaluation of opportunities to improve environmental sustainability throughout the basin including the tributaries.	None

Comment #	Comment	Response	Revised Section
10-9	What % of tows transiting Ohio River locks were empty (data in Section 4)? In Fig. 4-2, what percentage or number of tows are empty? What year does Fig 4.2 represent?	Most tows transiting the Ohio are a mix of empty and loaded barges. We do not model fully loaded tows or fully empty tows. ORNIM was calibrated to 2001 WCSC data and utilized the following average percent empty barges per tow: Montgomery 35.7% empty barges Greenup 41.2% empty barges Myers 34.1% empty barges The percent empty is sensitive to commodity type. Future shipment lists generated for forecast traffic will have slightly different percent empty ratios because tow commodity make up will vary. The purpose of Fig 4.2 is to simply show the uniformity of traffic arrivals along the Ohio River. Arrivals are fairly uniform across the year, month, week and day. LPMS 2001 data were used.	None
10-10	What are detailed numerical cost advantages of river vs. other transport modes?	A general rule of thumb provided by transportation specialists at TVA quote barge transportation rates at about 3/4 of rail and 1/8 of truck, on average, in the Ohio River Basin (ORB).	None

Comment #	Comment	Response	Revised Section
10-11	If barge transport is such a cost advantage, why do many generating plants have rail options for delivers? He understands that plants are adding rail capability, not barge capability, what is reason for that decision?	Shippers attempt to optimize choice by developing and utilizing competition between modes. The 2003 unscheduled Greenup closure made some shippers aware of costly over dependence on water; they need greater supply flexibility. A mix of truck, rail and barge transportation options allows a shipper to take advantage of more competitively priced transportation opportunities. If plants are adding rail capacity relative to barge capacity – this might suggest shipper perception that the existing waterway infrastructure is degrading and becoming less reliable. Continued under investment in maintenance will only exacerbate this perception.	None
10-12	In light of flat traffic from 1994-2004, why is there only traffic growth (Fig 4, page ES-7)? Is there no scenario under which growth would continue to be low or negligible? Could not the same conditions continue that caused the lack of growth from 1994-2004?	We believe that the Clear Skies Scenario reflects a reasonable low-growth outcome for the Ohio River. Under Clear Skies, utility steam coal traffic (which makes up about half of total traffic) initially declines and then flattens at a level below the coal traffic levels of the mid-1990s. For the total traffic forecast over the 2000-2030 period the annual growth rate is about 0.6 percent per annum, or less than one-third of the historical (1970-2000) growth rate of about 2.1 percent. Since the mid 1990s Ohio River traffic has been affected principally by a near total loss of foreign export coal traffic, the effects of increasingly stringent environmental regulations and, in certain years, by lengthy shutdowns at major coal-fired electric generating plants. The Clear Skies Scenario reflects an evolution of increasingly stringent environmental regulations, with the expected dampening effects on Ohio River traffic.	None

Comment #	Comment	Response	Revised Section
10-13	Statement that future navigation investments would not adversely impact long-term resource sustainability contradicts claim that they (navigation investments) are responsible for failure of these species to achieve sustainability.	Navigation investments are only one of many past, present, and future actions that affect the sustainability of resources on the Ohio River. The study concludes that future navigation investments will result in slightly improved environmental conditions over existing operations due to a decrease in transit times.	None
10-14	There is no discussion of flooding impacts from increasing river level from 18 inches to 13-35 feet pool levels. What are impacts resulting from higher pool levels created by the current lock/dam system? Have there been prior studies that address this issue, if so, provide citations.	The navigation dams are designed to create navigation pools. When river levels reach the top of the dams, the river is essentially run-of-river which means the dams have no added effect on river levels. Flood levels are the same as if there were no dams.	None
10-15	Disagree with statement that congestion fees "do not address the maintenance and structural investment needs of the mainstem." If congestion fees have the effect of reducing some of the delays then would it not have an impact on the need for certain navigation investments?	Congestion is only a problem on the mainstem during a main chamber closure. It seems likely that a congestion fee would be most appropriately applied during these times in order to reduce the inefficient queuing of tows and allow the market to relieve congestion. Having said this, it is not clear how the implementation of a congestion fee will do anything to improve the structural integrity of an aging lock project. Congestion fees do nothing to prevent the normal aging and wear-and-tear of system infrastructure.	None

Comment #	Comment	Response	Revised Section
10-16	Does any Corps modeling take into consideration additional rail access of utilities or environmental or economic costs of operating the barge system now and in the future? Describe or why not?	One of the forecasting approaches considers improved rail access of utility plants inasmuch as this improved rail access is reported by the electric utilities in their survey responses. The alternative approach (the linear programming approach) considers only existing receiving capabilities of the electric utility plants. The environmental impacts of operating the barge system are specifically modeled (NAVPAT). The economic costs of operating the barge system are specifically modeled as well.	None
10-16	Nationally, the Corps has identified that its P&G manual limits its ability to more completely adopt practices using current methods of economic/environmental analysis and stewardship. Disappointed that this was not identified as a constraint in ORMSS and call for updating the P&G to current economic/environmental standards.	Our responsibilities (at the District level) in carrying out general investigation studies such as the ORMSS do not include assessing the appropriateness of P&G guidelines. We do, however, firmly believe that we are able to properly formulate and evaluate alternatives in compliance with current P&G requirements and that this report fully meets those requirements. Therefore, we should not be expected to identify the P&G as a constraint in our completion of ORMSS or call for an update of the P&G. If others in the Administration or Congress succeed in modifying the P&G by changes in laws or Administration policy, we (Corps) will certainly follow whatever the changes turn out to be.	None

Comment #	Comment	Response	Revised Section
10-17	Corp continues to take no action to mitigate for negative impacts from its operations which endangers further recovery and continues to suppress local economies of many Ohio River communities. It must demonstrate stewardship by not delaying any further mitigation measures. (The report) does not recommend any actions be taken now at the locks and dams to improve the ecology of the river, even though it identifies specific measures (Table 6-5) that could and should be taken. Those remedial measures that are related to Corps projects and operations should be listed in Table 6-6 (EnvironmentalSustainability Strategies Under the Navigation Stewardship Program). The identified measures will mitigate impacts at the locks and dams now and do not require funding under the authorized Ohio River Ecosystem Restoration Program.	Mitigation has been added to the final report under section 10.4.1. Regarding your comment concerning specific measures identified in Table 6-5 that the Corps should take now at the locks and dams to improve the ecology of the river, we would like to respond by first explaining our general capability for approaching ecosystem restoration and mitigation before we discuss the specific actions we intend to take pursuant to the SIP. Whereas most agencies with environmental missions were created through organic legislation that empowered them to use their discretion to fund authorized activities, the Corps of Engineers has no such programmatic authority. The Corps pursues missions such as navigation and ecosystem restoration as agreed upon between Congress and the President through project-specific legislation. Corps projects are authorized through Water Resources Development Acts and funded through annual appropriations bills. Implementation of the ecosystem restoration and mitigation measures would require a dedicated stream of funds and specific authorization to carry out. We currently lack both of these requisites. Also, since the SIP is a planning document and is not meant to go forward for Congressional authorization, we don't see obtaining them through this study. To address more systemic issues related to the navigation system, the Corps will incorporate several environmental components into future site specific studies that this report recommends: evaluation of fish passage strategies at each lock and dam along the Mainstem during studies for lock modernization and major rehabilitation; continuance of the Interagency Working Group concept at the local level to participate in and to review and comment on future studies as they progress; identification, description, and quantification of riverine habitat within the individual project's area of influence; incorporation of sustainability planning within each individual project's area of influence; and, if a non-federal partner is identified, development of an Environmental Restoration Plan that will become part of the Combined Plan for authorization of each site specific project. As required for navigation investments, however, all separable restoration costs will require a cost sharing partner.	10.4.1

Comment #	Comment	Response	Revised Section
11-1	The fact that the ERP is authorized, but as yet unfunded, should be more clearly communicated throughout the discussion of ecosystem sustainability and restoration issues addressed by the ORMSS study reports.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary and Other Sections
11-2	Study recommendations should be presented in a manner that reflects the study conclusion that "high priority ecosystem sustainability measures are needed..." The recommendation for an Ohio River Navigation System Investment Plan should explicitly include the integration of ecosystem restoration analysis and decision making within the expanded program capacity.	The recommendations in the Executive Summary include the following: " Pursue planning and implementation of measures to improve environmental sustainability in collaboration with other interests."	Executive Summary
11-3	Environmental improvements to the Ohio River ecosystem would benefit from incorporating the following as additional recommendations of the ORMSS Study: • Implement pilot or demonstration projects under the ERP concurrently with the preparation of the Program Implementation Plan. • Amend the ERP authorization to expand to the entire Ohio River basin and allow cost sharing by non-governmental organizations.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization precludes implementing these recommendations.	Executive Summary and Other Sections
11-4	Any discussion of measures to reduce the impacts of lock and dam maintenance should include mooring cells. When available, mooring cells help to reduce tow queuing impacts and conserve fuel consumption by providing a tie-off point that allows tows to shut down their engines during lock passage delays. There does not appear to be any reference to mooring cells in the Executive Summary.	Mooring cells require little if any maintenance and therefore are not a factor in discussions of lock and dam maintenance (by the Corps). The benefits noted apply to the towing industry. The Corps will continue to maintain all of their existing mooring cells on the Ohio River mainstem.	None

Comment #	Comment	Response	Revised Section
11-5	The discussion of minor repairs and small jobs is confusing. These actions (as well as measures such as N-up/N-down lockage to reduce impacts of such actions) are present in the WOPC and in all alternatives under the WPC. The difference is the extent to which more progressive (WPC) repair strategies can reduce the impacts of increasingly frequent repairs under the WOPC. The conclusion regarding "Minor repairs and small jobs..." should be deleted.	This conclusion is consistent with text in Section 8.3.1.1, specifically, that such work involves few, if any, environmental impacts associated with routine operations and maintenance. Further, this work is not a function of more progressive repair. This work is broken into "Normal O&M" and "Random Minor" categories in tables 8-8, 10-6, 10-9 and 10-12 (the first for the Without Project Condition and the latter three for With Project Alternatives involving more aggressive maintenance). Note that the expenditures are the same or nearly the same for all traffic scenarios and across alternatives, i.e. $46.7M for Normal Routine O&M and $2.2-$2.4 million for Random Minor, signifying the lack of influence of more aggressive maintenance on these routine expenditures.	None
12-1	Cannot support study findings in the absence of funding of the Ohio River Ecosystem Restoration Program.	Noted.	None
12-2	Conceptually agree with schedule of navigation investments.	Noted.	None
12-3	It is essential that future Congressional appropriations for navigation improvements be coupled with comparable funding of the Ohio River Ecosystem Restoration Program. Without funding for the ERP, the Corps will not achieve its stated goals of environmental sustainability for the river and its environs.	The Ohio River Ecosystem Restoration Program is now eligible for deauthorization. The fact that it is yet unfunded and eligible for deauthorization will be more clearly communicated throughout the final report.	Executive Summary, Sections 2.2.1, 3.2, 8.5.1, 8.9.2, & 10.2.2.2 and TABLE 9-10

Comment #	Comment	Response	Revised Section
12-4	The Ecosystem Restoration Program and the navigational improvements cannot be undertaken separately and then considered simultaneously when it is convenient to do so, especially when restoration efforts have yet to be funded. The current SIP/PEIS does not meet its stated objectives because it is premised on full funding of separate programs with separate appropriations.	Noted.	None
12-5	The environmental sustainability of all aspects of the Ohio River aquatic community is assumed to continue to improve over time. Some increases may occur if water quality continues to improve, but little hard evidence that water quality will improve significantly beyond current conditions.	All of our methodologies, definitions, and assumptions used in our analysis are provided in the CEA Chapter 3.	None
12-6	Nonpoint source pollution is currently and will continue to be the primary factor affecting fish communities and aquatic life and will increase in the river over time.	Nonpoint source pollution is an important factor influencing fish communities. However, programs are being developed and implemented to reduce key sources such as combined sewers, runoff from disturbed sites, and acid mine drainage.	None
12-7	The potential impacts of all invasive species, such as the Asian snakehead, are not addressed.	Several invasive species, including some not yet confirmed in the Ohio River, were recognized in the report. It would be virtually impossible to address all possible invasive species that may appear over the planning horizon.	None
12-8	Improvements in navigation structures to allow greater between pool dispersal of native fish would likely also hasten and facilitate the invasion of exotic species. Efforts to improve long-term connectivity of native populations may result in their ultimate demise.	We recognize that facilitating interpool movement of fishes would make it easier for invasive species to disburse throughout the river. During a discussion with the IWG regarding fish passage, there was consensus that the system currently in place would not serve as an effective barrier to invasive fish species.	None

Comment #	Comment	Response	Revised Section
12-9	Sustainability will require: federal regulation of and incentives for reduced nonpoint source pollution; strict federal limits on floodplain development of public and private lands; restoration and protection of in-river habitat features; additional controls on the introduction of invasive species; and federal funding for research to determine the invasive potential of numerous aquatic species.	This was indeed a concern of the resource representatives on the Interagency Working Group and the resource experts consulted on sustainability needs. It was the group consensus, however, that positive benefits of connectivity outweighed the negatives.	None
12-10	The potential influences of global climate change on the Ohio River ecosystem or its contributing watersheds are not mentioned.	CEQ Guidelines stress the need to define geographical and temporal limits on the analysis because "it is not practical to analyze the cumulative effects of an action on the universe". Localized impacts caused by global warming are still theory and not suitably forecast for meaningful analysis.	None
12-11	ORMSS does not evaluate the incorporation and development of hydroelectric power projects during repair and modernization of the navigation structures. Why isn't hydroelectric and alternate energy production evaluated in the SIP/PEIS?	Hydropower is not a Corps mission and no considerations are given to hydropower when operating the L/D. Federal development of hydropower dams comes under the authority of the Federal Energy Regulatory Commission and would require a separate authority. At this time, there we see no indications that this will occur.	None
12-12	Environmental sustainability is addressed in qualitative terms. Bar charts can not be evaluated in any meaningful way as there is no stated scale identified for the y-axes. All of these evaluations only consider best-case outcome for all factors discussed. The inclusion of pseudo-quantitative data that portrays only best-case scenarios is not appropriate as a basis for future decision-making.	CEQ Guidelines acknowledge the difficulty of assessing sustainability. Their guidance was to identify predefined thresholds. In the absence of thresholds, national, regional, state or community goals should be used. The Corps attempted to use this guidance by identifying indicators of sustainability and got the concurrence for these from the IWG. Once established, these became the measures of sustainability; the bar charts serve merely as a graphic aid to portray the findings.	None

Comment #	Comment	Response	Revised Section
12-13	The final draft report should incorporate any impacts from ORSANCO rulemaking proposal (relaxation of bacterial loading allowances based on river flow rates) on recreational users.	ORSANCO is cooperating with several other entities to develop an Ohio River Total Maximum Daily Load (TMDL) for bacteria. This is a work-in-progress with an unknown outcome. Speculation regarding the final TMDL or its effects is premature at this time.	None
12-14	This report does not include a consideration of current research on larger river systems conducted at the University of Louisville and elsewhere. The latest research and findings related to large river ecosystems should be considered and incorporated into decision-making processes over the projected 60-year span of ORMSS and its component studies.	The report draws on a large body of knowledge of large rivers from a number of researchers.	None
12-15	Many projections, models, and assumptions presented in the report do not include information for the stated 60-year scope of investigation (Sections 4, 8, 10 and 12 are cited, of the main report?).	We attempted to use current research augmented by primary research.	None
12-16	Numerous statements in the report and appendices do not provide any reference for the assertions made.	CEQ regulations require that NEPA documents are to be written in plain language that is understandable to the general public and to decision makers. Therefore citations were held to a minimum in the SIP/PEIS. Many more citations are used for statements made in the technical appendices.	None
12-17	Include them (info@riverfields.org) on mailing list for subsequent Corps actions on the ORMSS, SIP/PEIS, and ERP.	Noted.	None
13-1	Unless the ERP is fully implemented, it is difficult to discern how the Corps can claim success in improving ecosystem sustainability while balancing economic and environmental improvements.	While the Corps remains supportive of the ERP, the reality is that this program is now a candidate for de-authorization because no funds have been appropriated.	None
13-2	The IWG should be continued, improved upon, and include others partners.	Continuation of the IWG has been identified as a mitigation feature to be included in site specific studies.	10.4.1

Comment #	Comment	Response	Revised Section
13-3	Environmental restoration measures need to be implemented, not just identified, planned or designed.	We agree, implementation is essential to achieving environmental benefits. However, the program remains unfunded and is a candidate for de-authorization.	None
13-4	Conclusion of achieving sustainability of fisheries resources may be overly optimistic especially given habitat constraints, dams, exotic species, and other challenges discussed.	Noted. The assumptions used for that conclusion are stated. The Conclusions were also reviewed by the IWG.	None
13-5	Prediction of increasing sustainability for both mussels and riparian habitat may also be overly optimistic, no reasonable justification for this is provided.	Noted. The assumptions used for that conclusion are stated. The Conclusions were also reviewed by the IWG.	None
13-6	Adaptive management will not be effective without specific program authorization or funding.	Agree.	None
13-7	As no indication of black carp control is mentioned, the USGS suggests the 2005 publication (Nico, et al) to help develop a mitigation strategy for the Ohio River mainstem and tributaries.	We have added this reference.	5.2.2.1.2
13-8	Unless the term "exotic" is intended to refer only to species not native to any U.S. ecosystem, perhaps replacing the term with "nonnative" throughout the document would be more appropriate.	In this report, "exotic" is defined as not native to the Ohio River ecosystem.	None
13-9	Page ES-5, 1st paragraph, last sentence: It is stated here that the purpose of the ORMSS was "modified to include the identification of measures to improve ecological sustainability to improve a balance between economic and environmental improvements." We suggest reviewing the document to ensure a consistent project purpose is described throughout the document.	Revised Section 2.1 to use the same language as on page ES-5.	2.1

Comment #	Comment	Response	Revised Section
13-10	Page ES-9, 2nd paragraph, first and third sentences: This is a critical assumption that must be considered as the Corps reports on environmental sustainability of natural resources into the future. The estimates of future environmental sustainability "assumes full implementation of the as yet unfunded Ohio River Ecosystem Restoration Program and 14 specific types of measures (26 total specific environmental sustainability measures)..." Short of full implementation, efforts will fall short of successfully improving environmental sustainability and balancing economic and environmental improvements. This is critical and should justify new authorities for the Corps to be able to fully implement the Restoration Program and the identified measures.	The Ecosystem Restoration Program is now a candidate for de-authorization because the program has never been funded. This is a provision of Water Resources Development Acts. As it does not appear likely the program will be funded, the assumption that it will be fully implemented has been eliminated from both the without and with project conditions. It should be noted that full implementation of the program would not have brought resources into full sustainability. At best, it would have contributed to improving 2-3% of resources adversely affected by human activities.	8.5.1, 8.9.2, And Table 9-10,
13-11	Page ES-10, first two sentences: "the Corps will develop and implement Reasonable and Prudent Measures being identified." This language justifies a responsibility by the Corp to implement environmental restoration measures. It is unclear what the restoration authorities referenced in the second sentence are. We suggest adding text to clarify this issue.	Reasonable and prudent measures in this context are referring to outcome of the Endangered Species Act Section 7 Consultation for on-going Operation and Maintenance. The restoration authorities include all ecosystem restoration authorities available to the Corps. The text has been modified to make this clear.	ES-5.a.2).
13-12	Page ES-13, last paragraph: "The added components of the Moderate Plan would require funding in addition to that provided for the Ohio River Ecosystem Restoration Plan." To our knowledge, that plan has not received funding. It is unclear how will these and other identified restoration measures, necessary to improve environmental sustainability be funded.	References to the Ecosystem Restoration Program have been eliminated from both the Without and With Project Conditions. The sustainability measures were developed without constraints of funding, responsibility, implementation concerns, etc. The effort was focused only on identification and agreement on highest priority needs of the resources.	ES-5.a.2), And ES-5.b.2).
13-13	Page ES-14, 1st sentence: "the need for new or modified authorities" is at least in part identified in the CEA. Is there an Implementation Plan for the Restoration Program or is this awaiting funding?	The Ecosystem Restoration Program authority provides federal funding to prepare a Program Implementation Plan.	None

Comment #	Comment	Response	Revised Section
13-14	Page ES-14, last sentence: There is a discrepancy here; how does this study provide "the means to optimize returns on investment" if the needed authorities and appropriations do not exist to implement the needed restoration actions to improve ES? We recommend adding text to remove this discrepancy.	The majority of the needed authorities do exist and are funded although some only marginally. Only the Ecosystem Restoration Program, among the array of restoration programs, lacks appropriations. See Section 8.5.1 for the list of Corps authorities and Table 8-7 for other agency authorities.	None
13-15	Page ES-15, 7th bullet: New authorities may be necessary to implement some restoration measures with 100 percent full Federal funding. The Environmental Sustainability of fish resources is also dependent upon such authorizations and appropriations for implementation of the identified environmental restoration needs. We suggest adding text that addresses this point.	The Corps does not have any restoration authorities that provide paying for measures with 100% federal funds nor does its policies allow for such an authority. Chapter 4 of the CEA lists the assumptions made in predicting full sustainability for fishes considering future reasonable actions.	None
13-16	Page ES-16, 3rd bullet: Follow-on studies are recommended to include environmental restoration measures to improve environmental sustainability.	This sentence was modified to address the concern.	ES-16
13-17	Page ES-16, 6th bullet: We suggest adding fish to last sentence. This bullet is good biological justification for the needed environmental restoration measures, but should go a step farther to conclude that new authorizations and appropriations are warranted to ensure environmental sustainability improvements.	This sentence was modified to address the concern.	ES-16
13-18	Page ES-16, last bullet: This study may have been assessed in accordance with the Corps Operating Principles, but without necessary authorization and appropriations to implement environmental restoration measures, it is unclear how this project will be implemented. We suggest adding clarifying text.	This bullet is only intended to state our compliance with our internal Operating Principles. The need for restoration measures is stated elsewhere.	None

Comment #	Comment	Response	Revised Section
13-19	Page ES-17, 2nd bullet: the results of the CEA are dependant upon the implementation of the identified restoration measures. Without large-scale implementation, many of the natural resources would not be expected to become fully sustainable and could potentially degrade. We suggest you review this bullet and provide text that addresses this issue.	Of the 87 RFFAs identified, the ERP was one. Because so many other actions affect resources, elimination of the program would not substantially change CEA results.	None
13-20	Page ES-17, 5th /6th bullets: We recommend system improvements at Meldahl, Hannibal, Myers, and Pike Island (and other future LDs) include fish passageways, as appropriate.	Concur. Fish Passage has been identified as a system mitigation feature that will be addressed at the site specific level.	10.4.1
13-21	Page ES-17, 7th bullet: implementation of some restoration measures without non-Federal cost-share partners is needed for success. We recommend additional text be added to address issue.	Corps policy is that ecosystem restoration projects are usually funded at 65% Federal and 35% non-federal. Funding projects at 100% Federal expense is not supported by the Corps.	None
13-22	Page ES-17, 8th bullet: The Corps should maintain the IWG for implementation of this Program and other identified restoration measures.	Noted. 10.4.1	
13-23	Page ES-18, 1st bullet: This recommendation should include an environmental component. The IWG should also be included in this new stand alone program for consultation on environmental considerations.	The Ohio River Navigation System Investment Program is intended to expand the ORMSS to the dams and tributary structures. This program would have a strong environmental component and would include establishment of an IWG.	None
13-24	Env Appendix – CEA Chapter 1): General comment – Text in this section identifies a responsibility of the Corp to implement environmental restoration measures, not just identify or plan unfunded projects. We believe justification exists for the Corps to seek broad environmental oriented authorization independent of, or in conjunction with, system improvements and we encourage the Corps to do so.	The Corps has been seeking funds to implement ecosystem restoration measures. To date, these efforts have not been successful, and the Ecosystem Restoration Program is now a candidate for de-authorization.	None

Comment #	Comment	Response	Revised Section
13-25	Env Appendix- CEA Page 1-3: 1.3.1 Environmental Operating Principles – These principles provide terrific justification throughout the document for the responsibility of the Corps to act and implement Environmental Sustainability approaches into Corps SOP for "process and work". We support these principles.	Noted.	None
13-26	Env Appendix - CEA Page 1-3, 3rd paragraph: This paragraph defines Environmental Sustainability and provides additional key wording regarding an effective balance of economic and environmental considerations throughout all Corps process, including construction, operation, and maintenance. We recommend the Corps implement environmental restoration measures after appropriate identification, planning and design is done.	The Corps agrees that implementation is necessary to achieve ecosystem benefits.	None
13-27	Env Appendix - CEA Page 1-4, 1st paragraph, last two sentences: To a large extent, the greatest damages have already been incurred. We agree the incorporation of these principles can help to minimize additional impacts from future actions, but we believe they are most valuable to justify actions to minimize continuing effects of past actions.	Noted.	None
13-28	Env Appendix – CEA Page 1-4, last paragraph, 2nd sentence: "…will guide or prescribe alternative means…environmentally compatible navigation system…upon which future Corps actions will be based." We recommend the Corps include strong recommendations that will ensure that restoration measures will be implemented.	The Corps' recommendations include numerous restoration measures.	None

Comment #	Comment	Response	Revised Section
13-29	Env Appendix – CEA Chapter 4, P. 4-12, 2nd paragraph: The recovery of some fishes does not indicate that the sustainability of certain fishes will move to a sustainable level in spite of the navigation system. Water quality has improved and many fishes are now occurring in portions of the river that they had not been found in for years (even decades) prior, but active management practices (i.e., restoration stocking) may also explain the recovery of some species within the upper Ohio River. In addition, although some fishes may be re-colonizing portions of the river as water quality and management practices improve, the abundances of many fishes may still be much lower than historical levels due to maintenance of the navigation system. We recommend the Corps include in this paragraph that the level of sustainability of fishes is uncertain.	Operation and maintenance of the navigation system comprises only a few of the 87 reasonably foreseeable future actions potentially affecting fish communities. The rationale and justification for our conclusions is presented in Section 4.12.2.	None
13-30	Env Appendix – CEA Chapter 4, P. 4-12, last paragraph, 1st sentence: We question the value of this paragraph. The significance of such a comparison is minimal considering the different collection methods and without knowing the habitats where the electrofishing was conducted. Additionally, an electrofishing survey followed by a rotenone survey of the same lock chamber could yield differing results because of gear bias. We recommend this paragraph (and table) could be deleted without compromising the content of this chapter.	This is information from published literature and proves some background despite gear bias. We choose to keep this paragraph and the tables.	None
13-31	Env Appendix – CEA Chapter 4, P. 4-14, Introduced and Extirpated Species: These are such different topics that we recommend separating them into different sections. At a minimum, an additional level of sub-headings is needed to separate the two discussions.	Agree. The discussion has been separated by sub-headings.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-32	Env Appendix – CEA Chapter 4, P. 4-14, Introduced and Extirpated Species: This section needs to be rewritten. There are many incorrect or inaccurate statements within this section, especially within the bullets. Specific comments follow (next 14 comments):	This section has been extensively modified.	CEA Ch 4
13-33	Env Appendix – CEA Chapter 4, 1st sentence: It is likely that more than 14 fish species have been introduced into the Ohio River. We recommend deleting the first half of this sentence. The second half of the sentence needs to be clarified by replacing the word "had" with "known to have."	Note that this is by 1992 and is a cited literature source.	None
13-34	Env Appendix – CEA Chapter 4, 3rd sentence: We do not recommend using the adjective "important" to describe common carp. There are large numbers and biomass of common carp within the Ohio River, but this does not make them an important species. Although common carp have been in the United States since the late 1800's, this non-native species is still a concern to natural resources management agencies. Seven species of carp have been introduced into the US. Species of concern include common, bighead, silver, grass, and black. (Some could also argue that the goldfish is a management concern.) All of these species are established within the Ohio River except the black carp which is not considered established (yet) within the United States.	This has been changed to "a substantial component of the Ohio River fish community."	CEA Ch 4
13-35	Env Appendix – CEA Chapter 4, 2nd paragraph: This is incorrect. Three of the four species listed were already in the Ohio River before the 1993 and 1995 floods. These fish escaped to the river from many potential sources, but very few are documented. Grass carp likely first escaped from a USFWS facility and have been actively stocked all across the country.	The reference to 1993 and 1995 floods has been removed.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-36	Env Appendix – CEA Chapter 4, 1st bullet: Black carp have not established reproducing populations anywhere in the US; small sport fisheries do exist for common and grass carp; bow fishing for Asian carps is growing in popularity. We suggest including this information in this bullet.	This has been corrected.	CEA Ch 4
13-37	Env Appendix – CEA Chapter 4, 2nd bullet: Grass carp and common carp have distinctly different feeding niches and behaviors. Common carp uproot vegetation but do not "feed aggressively" on plants. We suggest including this information in this bullet.	Text has been revised to reflect this information.	CEA Ch 4
13-38	Env Appendix – CEA Chapter 4, 3rd bullet: Please include here that native larval fish do feed on plankton and may compete with bighead and silver carps for food resources if plankton becomes limiting. Competition requires a limited resource; plankton are not limited at this time. Some dietary overlap may also exist with native planktivores such as gizzard shad, paddlefish, and bigmouth buffalo.	Information included in text.	CEA Ch 4
13-39	Env Appendix – CEA Chapter 4, 4th bullet: Among other reasons, population studies are made difficult by the fact that standard sampling gears and fishing techniques for native fishes are not effective at sampling bighead and silver carp. Bighead carp rarely if ever jump from the water except when sampled by electrofishing gear. Silver carp and the occasional grass carp are known to jump from the water. The silver carp is the fish of concern relative to their jumping behavior and their potential to injure biologist, as well as recreational boaters and fishers. Please include this information in this bullet.	This is a literature citation.	None

Comment #	Comment	Response	Revised Section
13-40	Env Appendix – CEA Chapter 4, 5th bullet: Black carp do not compete for food with native fish species at all life stages. They will compete for food with native molluscivores if food resources are limited. Animals of riparian zones are only likely to be affected if they are dependent upon molluscan resources and these resources are limited in availability. This sentence should be cited. The black carp is not in the process of being listed as an injurious wildlife species. An important distinction is that it has been petitioned for listing and is currently being considered for listing, but a decision to list has not been reached. We suggest adding text to clarify this.	This information has been added to text.	CEA Ch 4
13-41	Env Appendix – CEA Chapter 4, P. 4-15, 1st paragraph: This paragraph has no relevance to the discussion of introduced species in the Ohio River and we suggest it be removed.	Paragraph removed.	CEA Ch 4
13-42	Env Appendix – CEA Chapter 4, P. 4-15, 2nd paragraph: The release of the Asian carp management plan needs to be updated from mid-2005 to August 2006. Please note that this document should be available at www.anstaskforce.gov in August 2006.	Text revised to reflect this release date.	CEA Ch 4
13-43	Env Appendix – CEA Chapter 4, P. 4-15, 2nd paragraph: Change third sentence to read "The potential impacts."	Text changed.	CEA Ch 4
13-44	Env Appendix – CEA Chapter 4, P. 4-15, 3rd paragraph: Delete text before "Pearson". The sentence should begin "Pearson and Pearson (1989) reported…"	Text changed.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-45	Env Appendix – CEA Chapter 4, P. 4-15, 3rd paragraph, line 5: We suggest this change to this sentence "…may interfere with migratory species such as paddlefish and sturgeons (shovelnose and lake)…"	Text changed.	CEA Ch 4
13-46	Env Appendix – CEA Chapter 4, P. 4-15, 3rd paragraph, last three sentences: The second and third sentences should be inverted. The collection of the juvenile lake sturgeon should be cited. If juvenile lake sturgeon have been stocked in the upper Ohio River or tributaries this sentence is not relevant.	Text changed.	CEA Ch 4
13-47	Env Appendix – CEA Chapter 4, P 4-16, next to last paragraph: We suggest the referenced species and reproductive guilds need to be verified. We believe that lake sturgeon are lithophils, the same as shovelnose sturgeon.	Text changed.	CEA Ch 4
13-48	Env Appendix – CEA Chapter 4, P. 4-16, last paragraph, 1st sentence: delete text following "in the river."	Text changed.	CEA Ch 4
13-49	Env Appendix – CEA Chapter 4, P. 4-22, 2nd paragraph, 1st sentence: change "jurisdictional" to "interjurisdictional."	Text changed.	CEA Ch 4
13-50	Env Appendix – CEA Chapter 4, P. 4-24, 4th sentence: This discussion down plays the effects of mainstem dams on native fishes. There is a wealth of literature that attributes increases in the abundance of lacustrine fishes and decreases in riverine fishes to the construction and maintenance of mainstem dams. Movement data also indicate that dams affect fish movements. Dams have affected habitat availability and connectivity, directly affecting fish abundance and survival. We suggest including language here that reflects this information.	Paragraph not changed. The ensuing paragraphs describe results of studies conducted on as part of the ORMSS on fish passage relative to dams.	None

Comment #	Comment	Response	Revised Section
13-51	Env Appendix – CEA Chapter 4, P. 4-25, last paragraph: The 1st sentence illustrates that anglers are well aware of the fact that dams stop longitudinal movements of fishes. Targeted effort (p. 4-26) is for migratory species. We suggest clarifying language reflecting these thoughts be included.	Text modified to reflect this.	CEA Ch 4
13-52	Env Appendix – CEA Chapter 4, P. 4-27, 3rd paragraph, 2nd sentence: We do not believe correlation (or coincidence) means causation. The amount of lockage events only suggests that there are opportunities for fish to move upstream through locks, but does not indicate that the "fish generally move" through locks. We suggest including language that shows locks to be ineffective as a passageway for riverine species, especially in biologically significant numbers.	Locks have been shown to provide opportunities for upstream movement in addition to that provided via gate passage.	None
13-53	Env Appendix – CEA Chapter 4, P. 4-28, A2: Operational modifications that would minimize head difference at a single gate would likely create more meaningful opportunities for upstream movements than through lock chambers. Meaningful modifications of locks or dams will be very site specific because of hydrologic variation between each. Please include clarifying language here that reflects these thoughts.	This is discussed in Section 4.8.1.3.	None
13-54	Env Appendix – CEA Chapter 4, P. 4-28, A3: This discussion downplays the effects of dams on the native fish populations. Please include language that indicates pre-dam fish distribution and recent information demonstrate the effects of limited movement of fish due to dams.	This comment does not pertain to answering Q.3. Further, these Q&As were developed during a structured discussion with the IWG. It would be inappropriate to add information not drawn from this discussion in this series of Q&As.	None

Comment #	Comment	Response	Revised Section
13-55	Env Appendix – CEA Chapter 4, P. 4-28, A4: Importance of downstream movements is downplayed. Please include text that indicates downstream fish movement is likely to be important, but that information on this subject is not well documented. Paddlefish have been demonstrated to move out of the Ohio River and then throughout the open portions of the Mississippi River and its tributaries. We suggest including text that downstream movement may also be important in the transport of mussel glochidia.	These Q&As were developed during a structured discussion with the IWG. It would be inappropriate to add information not drawn from this discussion in this series of Q&As.	None
13-56	Env Appendix – CEA Chapter 4, P. 4-29, A5: Big river species are actively managed by natural resources management agencies. Management practices, including restoration stockings, may contribute to upstream recolonization by some species. We suggest including these sentences.	These Q&As were developed during a structured discussion with the IWG. It would be inappropriate to add information not drawn from this discussion in this series of Q&As.	None
13-57	Env Appendix – CEA Chapter 4, P. 4-29, A6: Although adequate fish hosts may occur in the upper river, these fishes may be present in too low of abundances. Dams could be limiting abundances of important fish host species. Dams may also be preventing adequate movement of glochidia infested fish hosts past dams. We suggest including these sentences.	This may be true, but A.6 is based on a report prepared for the ORMSS by Ohio State University.	None
13-58	Env Appendix – CEA Chapter 4, P. 4-29, 4.8.1.3, 2nd sentence: We suggest changing to "Some fish" are able to migrate…	Text changed.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-59	Env Appendix – CEA Chapter 4, P. 4-29, 2nd paragraph: We suggest including language that indicates not all fish species can migrate through dams during periods of high velocity, that there are numerous migratory species of varying size and swimming abilities, and that connectivity was available at all flow conditions prior to the construction of the dams.	Although the Fish Passage research was inconclusive, it could not rule out that some fish species are blocked from migration by the dams. The text was modified to include the language provided in your comment.	CEA Ch 4
13-60	Env Appendix – CEA Chapter 4, P. 4-30, 1st paragraph: Please include that fish passageways should be constructed.	The report identifies fish passage as a systemic need and includes consideration of it at all L/Ds as a mitigation need. Text added to this paragraph.	CEA Ch 4
13-61	Env Appendix – CEA Chapter 4, P. 4-30, 3rd paragraph, last sentence: A citation should be provided for this statement.	This sentence was deleted.	CEA Ch 4
13-62	Env Appendix – CEA Chapter 4, P. 4-30, 3rd paragraph: Please include in this paragraph that the presence of fish hosts does not mean there are adequate abundances of host species or adequate movement throughout the river to allow for mussel populations to sustain, let alone expand.	This language was added to the text.	CEA Ch 4
13-63	Env Appendix – CEA Chapter 4, P. 4-30, 4th paragraph, 1st sentence: Change sentence to both upstream and downstream movements of "some" fishes…	Text changed.	CEA Ch 4
13-64	Env Appendix – CEA Chapter 4, P. 4-30, 4th paragraph, third sentence: It should be noted here that the abundance of fish hosts and ability of fish hosts to move upstream and downstream past dams may be affecting the reestablishment of mussel communities.	The mussel experts at OSU do not concur. See 4.8.1.2.	None
13-65	Env Appendix – CEA Chapter 4, P. 4-30, 4th paragraph, line 9: Please indicate here that fish passage facilities should be constructed and not just considered.	The report identifies fish passage as a systemic need and includes consideration of it at all L/Ds as a mitigation need.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-66	Env Appendix – CEA Chapter 4, P. 4-33, 1st full paragraph, 2nd sentence: We suggest clarification of the terms main channel and artificial in this text to make it more meaningful.	This is clarified in Tables 4-7 and 4-8 which were referenced at the beginning of this paragraph.	None
13-67	Env Appendix – CEA Chapter 4, P. 4-34, last sentence: We suggest including the following: Tributaries, which were demonstrated to provide important winter refugia, are often disconnected and are not available for fish to access.	This sentence was modified to address the concern.	CEA Ch 4
13-68	Env Appendix – CEA Chapter 4, P. 4-35, 7th and 8th paragraphs: We suggest including information on the importance of low flow refugia during cold water temperature that was demonstrated in this and other studies. We suggest the phrases "although some concern" and "relatively sheltered" be explained more fully.	Text was modified to clarify ambiguous wording. Refer to Environmental Appendix, Volume 2, Report titled "Winter Habitat Used by Fishes in Smithland Pool and Belleville Pool, Ohio River" for detailed information on importance of low flow refugia during cold water temperatures.	CEA Ch 4
13-69	Env Appendix – CEA Chapter 4, P. 4-39, 3rd paragraph, last sentence: Change "appears to aggressively" to "has the potential to …"	This sentence was modified to address the concern.	CEA Ch 4
13-70	Env Appendix – CEA Chapter 4, P. 4-49: 4.10.2: We suggest including here that canalization and O&M of the navigation system prohibit natural disturbance process important to the continual development and heterogeneity of riverine habitats.	Droughts and significant flood events continue to occur on the Ohio River mainstem. Mainstem dams do not have the capability to store floodwaters; their only purpose is to maintain a minimum nine foot navigation channel to provide year round navigation.	None
13-71	Env Appendix – CEA Chapter 4, P. 4-53, 1st paragraph, last sentence: We suggest including in this sentence that the negative effects of Asian carp and most other invasive species have not been demonstrated. (The exception is zebra mussel effects on native mussels.)	This sentence was modified to address the concern.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-72	Env Appendix – CEA Chapter 4, P. 4-57, 2nd sentence: Natural climatic events will have minimal effects as the Corp manages to prevent the habitat changes that are driven by natural events. "Unnatural" projects that create disturbance and habitat heterogeneity will have the greatest positive effects as long as the river is canalized and dammed. We recommend the Corps seek opportunities to allow for natural disturbance process to create habitat in off channel areas.	The Corps does not manage the Ohio River mainstem to prevent habitat changes that are driven by natural events. As stated above, dams on the Ohio River do not store floodwaters. Also, natural disturbance processes in off channel areas continue to occur as events dictate.	None
13-73	Env Appendix – CEA Chapter 4, P. 4-64, last bullet: We suggest including here that the Environmental Sustainability of fishes would decline in the short-term and will only improve substantially towards Environmental Sustainability if the restoration measures are implemented.	Of the 87 RFFAs identified, 61 were determined to have moderate to high potential to affect fish communities. Ecosystem Restoration was just one of these 61. Unfortunately, the Ecosystem Restoration Program appears to be a missed opportunity as it would contribute to improved sustainability. However, given that so many other actions are also affecting fish communities, the overall conclusion would not change substantially in the absence of this program.	None
13-74	Env Appendix – CEA Chapter 4, P. 4-65, 2nd paragraph: We suggest including text here stating that riparian habitats are important to processes for improving water quality and nutrient cycling; and processes that are important to fish, mussels, and other natural resources.	A sentence was added.	CEA Ch 4
13-75	Env Appendix – CEA Chapter 4, P. 4-66, 2nd paragraph: We suggest including language that the availability, connectivity between, and access to complex habitat types that provide for spawning, nursery, feeding, and over-winter refugia is very dynamic.	A sentence was added.	CEA Ch 4

Comment #	Comment	Response	Revised Section
13-76	Env Appendix – CEA Chapter 4, P. 4-66, 3rd paragraph, 5th sentence: We suggest clarification of this sentence. Is this saying that the effects of the system of locks and dams were evident even before construction of the initial system was complete?	This sentence pertains to non-navigational activities. The sentence has been clarified.	CEA Ch 4
13-77	Env Appendix – CEA Chapter 4, P. 4-66, last sentence: We suggest including language here that the modern navigation system prevents many processes important to the sustainability of natural resources, including disturbance processes that drive the production of dynamic habitats.	Droughts and significant flood events continue to occur on the Ohio River mainstem. Mainstem dams do not have the capability to store floodwaters; their only purpose is to maintain a minimum nine foot navigation channel to provide year round navigation.	None
13-78	Env Appendix – CEA Chapter 4, P. 4-67, 1st paragraph: Include language here that the high lift dams have also reduced connectivity and movements of many riverine fishes.	Sentence added.	CEA Ch 4
13-79	Env Appendix – CEA Chapter 4, P. 4-67, 1st paragraph, last sentence: Include here that the importance of embayments have been documented, but many in the lower river are not accessible to fishes when they are most critical.	Sentence added.	CEA Ch 4
13-80	Env Appendix – CEA Chapter 4, P. 4-67, 1st paragraph, last sentence: Include here that the importance of embayments have been documented, but many in the lower river are not accessible to fishes when they are most critical.	Sentence added.	CEA Ch 4
13-81	Env Appendix – CEA Chapter 4, P. 4-67, 4th paragraph, 2nd sentence: Indicate where the results of these studies are summarized, at a minimum these studies should be referenced.	This sentence was modified to address the concern.	CEA Ch 4
13-82	Env Appendix – CEA Chapter 4, P. 4-67, last paragraph: Include in this paragraph how many Ohio River fishes are considered migratory?	There is no universal agreement on this topic.	None

Comment #	Comment	Response	Revised Section
13-83	Env Appendix – CEA Chapter 4, P. 4-67, last paragraph, line 12: We suggest including text here that open river conditions are less likely to occur in the upper river.	This has been added.	CEA Ch 4
13-84	Env Appendix – CEA Chapter 4, P. 4-70, last paragraph: Indicate in this paragraph where the results are discussed?	Location of results is now indicated.	CEA Ch 4
13-85	Env Appendix – CEA Chapter 4, P. 4-75: We suggest including language that pollution control efforts will continue to have positive effects on water quality and fishes, but that without habitat construction and connectivity, environmental sustainability of many fish species will remain marginally sustainable at best.	As stated above, many factors affect fish communities with restoration effort being among them.	None
13-86	Env Appendix – CEA Chapter 4, P. 4-75: We suggest including language here that the effects of Asian carp are over stated, that they are of concern, but effects have yet to be demonstrated or quantified.	Sentence modified as suggested.	CEA Ch 4
13-87	The projected ES bar graphs (figure 6-10 on page 6-31 and 10-19 on page 10-67) for mussels and riparian habitat still show an increase for the future. We suggest including here justification for the qualitative improvement predicted. These figures do not agree with others in the text, e.g., ES charts in Figure 6-6 and 6-7, and figure 10-10 and 10-11, but they should be the same. Both will likely remain marginally sustainable at best, but not more so in the future than now. We suggest a program to reverse the loss of riparian habitat from industrial, recreational and urban development.	Figure 6-10 does depict mussel resources improving in the future over the present although the resource is marginally sustainable throughout the study period. This does not agree with figures 6-6 and 10-10. We will correct figure 6-10. The full discussion of this assessment is in Chapter 5 of the Cumulative Effects Assessment (CEA) in the Environmental Appendix. The Figures for the Riparian resource will also be adjusted for consistency in all the figures. The full Riparian discussion is contained in Chapter 6 of the CEA.	Figure 6-10

Comment #	Comment	Response	Revised Section
13-88	Other existing authorities where the Corps can make a difference in future environmental quality is the Section 10/404 program. The Corps permit program has a direct effect on the quantity and quality of riverine and riparian habitat throughout the river systems. The document should stress the need for a unified approach within all the districts within the Ohio River Division on environmental sustainability; mitigation; baseline data needs and impact assessments; and compliance monitoring. This could be another column in table 9-10 as a means to enhance ecosystem sustainability.	Though not completely uniform, regulatory activities under the Section 10 and 404 authorities are guided by a common set of rules and guidelines. Although the SIP/PEIS is intended to guide future decisions on navigation improvements and ecosystem sustainability, the document, especially the CEA, could serve as a resource for many other purposes, including the Section 10 and 404 programs.	None
14-1	Letter of support.	Noted.	None
15-1	Letter of support.	Noted.	None
16-1	Disagrees with conclusion that the Lock Modernization Alternative will make a positive contribution to various resources, suggests that it would have less negative impacts than other alternatives.	The comment misrepresents the statement. The Conclusion states a reduction in cumulative effects is a positive contribution.	None
17-1	Supports Adaptive Management-Need to enhance AM discussion in final EIS; clearly identify the process, data needs and key steps that will be used.	CEA Chapter 13 contains discussion of adaptive management. Corps preference in site specific studies is to work with stakeholders to evolve a strategy wherein all participants interact.	None
17-2	Institutional Arrangements-There are a wide range of jurisdictions, organizations, ongoing authorized projects and other factors that influence the Ohio River Navigation System performance and ecological health. Describe course of action and schedule to define new authority & relationship to existing institutional arrangements. Formalize and continue collaboration on implementation of new management strategies.	Throughout the ORMSS, the IWG was instrumental in success of the effort. Means of continuing the IWG were explored, and while there was considerable support, the Corps would need authority and on-going funding to lead this effort.	10.4.1

Comment #	Comment	Response	Revised Section
17-3	Institutional Arrangements- Include institutional arrangements in the ROD. Include draft ROD in the Final EIS.	Following issuance of the final EIS, additional reviews will occur that could affect the Corps' decision. Therefore, it would be premature to include a draft ROD with the FEIS.	None
17-4	Environmental Justice-Additional focus should be given to census tracts where minority and/or low-income populations exceed state averages. Discuss how benchmark value of 1.5 times the state poverty level was determined.	This issue is not ripe for decision at the programmatic tier. This will be included in site specific NEPA documents. Benchmark value of 1.5 was selected by the study team as a measure to denote significance at this scale.	None
17-5	Cumulative Impacts and Mitigation Plan-Cumulative Impact analysis is incomplete without corresponding comprehensive system wide mitigation plan.	Concur. Section 10.4.1 (Mitigation) added.	10.4.1
17-6	NPDES Permitting- Recommends Corps undertake early coordination with bordering states on potential NPDES permit needs.	Agree. If NPDES permit requirements are identified, the Corps will obtain permits prior to discharge.	None
17-7	Hydroelectric Power Generation-Programmatic EIS should consider potential adjunct use of L/D impoundment structures serving as reservoirs for hydro power projects and if such use would impact lock operations.	Hydropower at Corps navigation dams use run-of-river flows; no considerations are given to hydropower when operating the L/D.	None
17-8	Structure Design for Fish Protection-Programmatic EIS should include a commitment to examine design of L/D structural modifications to promote the protection of aquatic life including portal passages.	Concur. Fish Passage has been identified as a system mitigation feature that will be addressed at the site specific level.	10.4.1
18-1	Sustainability concerns around habitat degradation, fragmentation and loss should be more fully addressed prior to issuing a final ORMSS. Plans to reduce these concerns must be included in site specific projects.	One piece of the mitigation plan in 10.4.1 is to prepare a sustainability plan within the area of influence of each site specific study recommended in the SIP.	10.4.1
18-2	Add a VEC for river ecosystem function as the fundamental support system for discrete VECs currently identified.	List of VECs to consider coordinated extensively with the IWG and public early in the study. Ecological Functions discussed within individual VECs.	None

Comment #	Comment	Response	Revised Section
18-3	WPC would like to identify clean gravel substrates to uses as refugia. River sections just below dams and select island locations will be the most promising, but also the most likely to be impacted during lock and dam modification work.	The Corps is very interested in the results of this effort.	None
18-4	The LMA will minimize degradation of natural resources but will not improve sustainability of resources in and along the Ohio River.	The comment misrepresents the statement. The Conclusion states a reduction in cumulative effects is a positive contribution.	None
18-5	WPC would like to participate with the Corps in the Ohio River Basin Comprehensive Study and other efforts to pursue planning and implementation of measures to improve sustainability.	Participation by the WPC in the Ohio River Basin Comprehensive Study would be welcome.	None
18-6	WPC formally requests to be notified of public participation opportunities related to Upper Ohio River Navigation Feasibility Study.	This notification and participation by WPC has occurred.	None
19-1	Add Section noting state-listed plant and animal species as an affected resource and as a resource of concern.	This issue is not ripe for decision at the programmatic tier. This will be included in site specific NEPA documents.	None
19-2	This proposal may require the formal approval of our agency pursuant to the Flood Control Act for any proposal to construct, excavate or fill in or on the floodway of a stream or other flowing waterbody which has a drainage area greater than one square mile.	This issue is noted but is not ripe for decision at the programmatic tier. This issue will be coordinated with the State of Indiana at the site specific level.	None

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Comment #	Comment	Response	Revised Section
19-3	Project programs not involving new lock and dam construction with improvement of some existing ones would perpetuate a condition of frequent backups at locks, which have negative impacts on aquatic habitats. However, new L/Ds with significant construction at old ones will result in permanent loss of aquatic and riparian habitat w/potential losses to mussel resources. An alternative that does not involve a permanent loss of habitat in and along the Ohio River should be selected. The LMA will result in the permanent loss of 2+ acres of aquatic habitat at upper Ohio River pools, may permanently eliminate fish habitat and mussel beds and cause extensive and lasting bank erosion including to river islands. The LMA could reduce tow queuing and the negative environmental effects it causes; however, the report indicates low-cost structural practices can minimize and in some cases eliminate tow queuing and its negative environmental effects. The LMA will cause significant environmental harm and is not recommended.	The LMA involves construction of a larger lock at Emsworth, Dashields, and Montgomery locks, in each case to replace the very small 56'x360' lock. These very small locks, designed for traffic that disappeared from the waterways by WWII, present bottlenecks whenever the main chambers are closed and all traffic is forced thru the auxiliary for extended periods of time. Low cost structural measures can not significantly affect queues during those times. In addition to having economic advantages, this study has shown that replacement of these outdated locks has environmental advantages as well, advantages that appear to be substantially greater than the negative effects of the permanent loss of habitat cited.	None
19-4	Recommendations of the Draft FWCA Report should be fully implemented by the Corps.	Noted.	None
19-5	Recent Corps project designs have included bank stabilization using large expenses of rip-rap, eliminating the existing riparian habitat, and riparian habitat connectivity.	Noted.	None

Comment #	Comment	Response	Revised Section
19-6	Recommendations: -revegetate all bare and disturbed areas -Minimize in channel disturbance and the clearing of trees and brush -Do not work in the waterway from April 1 through June 30 -Do not cut any trees suitable for Indiana bat roosting -Do not construct any temporary runarounds or causeways -Use minimum average 6 inch graded riprap stone extended below the normal water level to provide habitat for aquatic organisms in the voids -Appropriately designed measures for controlling erosion and sediment must be implemented -Seed and protect all disturbed streambanks and slopes	These issues are noted but are not ripe for decision at the programmatic tier. These issues will be coordinated with the State of Indiana at the site specific level.	None
20-1	Ohio River navigation system important to region and nation, (there are 45,000 people who derive their livelihood from the river directly and 217,000 direct/indirect and induced jobs dependent on this river {regionally}) and welcomes progress toward addressing needs at Emsworth, Dashields and Montgomery Locks and Dams.	Noted.	None

Comment #	Comment	Response	Revised Section
21-1	Disappointed that the report did not account for costs and impacts on everyday lives of residents incurred due to shift of river traffic to land modes that are caused by lock closures.	The Corps policy on accounting for these types of costs was being developed during the ORMSS study effort and therefore it was better that these costs were not included. Corps HQ did issue a memorandum on September 1, 2006 that stated or clarified the policy on "reduced travel benefits" related to the Southwest Arkansas Navigation Study. The basic findings were (taken from the Economics Appendix of the Upper Ohio Feasibility Scoping Meeting Package): 1) the reduction of congestion on overland modes (externality) is an indirect benefit that can be included as a NED benefit with the following qualification; 2) the externality cannot be used to determine economic feasibility, but can only be added after economic feasibility has been determined. Therefore the impacts of shifting traffic to land-based modes due to lock failures can be accounted for as an economic benefit with the above qualification. The on-going feasibility study considering new locks at Emsworth, Dashields and Montgomery will consider the following externalities: 1) Value of Travel Time (congestion) 2) Highway Safety 3) Fuel Consumption 4) Air Pollution The first of these can be accounted for as economic benefits after economic feasibility and has been determined.	None

Comment #	Comment	Response	Revised Section
22-1	Has there been any interest in addressing a recommendation from the USFWS to change the 65/35 (Fed/non-Fed) cost share to 90/10 for environmentally-related work.	No. Issues being discussed by Congress related to a possible WRDA include expanding the authorization of the Ohio River Ecosystem Restoration program to Ohio River tributaries and to allow NGOs to participate as project sponsors under that program.	None
23-1	Was there a projection as to how long the Ohio River Locks and Dams last?	Lock and Dams are designed for a 50-year life. Several Ohio River Projects are already past their design life.	None
23-2	Taking into consideration the design life, why weren't there provisions for needed repairs taken at projects already past their design life before now?	Federal decision makers must prioritize investments in nation's resources. This report provides information for decision makers to prioritize investments.	None
24-1	Based on experience with funding of projects like Kentucky & Olmsted, how can we know that the SIP can be funded implemented as indicated in the report?	We can not guarantee as to future funding. This report establishes the road map (for Ohio River maintenance needs) to allow for prioritization of federal investments and to address the issue raised.	None
24-2	Are statements supporting proposed program as important as dissenting views.	It is very important for stakeholders to state the value of the navigation system so that these views can be factored into the federal decision making process.	None
24-3	In Paducah, there's something on the order of 1,800 direct jobs associated with the river and 25,000 indirect jobs, a lot of people affected.	Statement of Support.	None
24-4	Have there been any discussions as to how to organize efforts to ensure funding for the recommended projects?	No, the Corps is not in a position to do that. Such decisions are worked out in budgets developed between the administration and Congress. Information like that provided in this report facilitates that process and subsequent decisions about how our nation's resources are allocated.	None

Comment #	Comment	Response	Revised Section
24-5	What would a maximum program mean in terms of employment for the Corps and the region in terms of people that would be involved directly with the Corps?	Little impact to Corps employment, construction would be performed by contractors. The majority of money required by these projects would go back into small and large businesses in the region.	None
24-6	What percentage of traffic on the Ohio is import and export, either northbound or southbound of the Gulf of Mexico?	The Corps does not maintain data on imports and exports and can not provide the requested information.	None
24-7	Northbound freight suspected to be more prominent, with apparent focus on upper three projects, the southern projects can't be allowed to deteriorate.	New locks are needed on the upper three locks due to age, but the entire system will be maintained to ensure that the entire river system is reliable.	None
25-1	Long-term perspective and funding for Ohio River Navigation System is needed.	Statement of Support.	None
25-2	Maintenance of nation's infrastructure such as recommended by this report is essential for current and future generations. 70-year perspective considered by study is impressive, funding for these needs is critical.	Statement of Support.	None
25-3	Needed perspective for funding (the Ohio River investment needs) likened to that for the Eisenhower's highway program considering associated improvements in productivity in the economy.	Statement of Support.	None
25-4	Similar to supporting comments that Mr. Morris made at Evansville, IN public hearing and discussed above.	Statement of Support.	None
25-5	Similar to supporting comments that Mr. Morris made at Evansville, IN public hearing and discussed above.	Statement of Support.	None
25-6	Similar to supporting comments that Mr. Morris made at Evansville, IN public hearing and discussed above.	Statement of Support.	None

Comment #	Comment	Response	Revised Section
26-1	Could auxiliary locks be slowly converted to full service locks to help cope with increased traffic and during needed maintenance?	No. The only way for auxiliary locks to provide the same service as a larger main is if they are enlarged (reconstructed) to the size of the main chamber.	None
27-1	Need to maintain Ohio River System and for provision of 1200' auxiliary chambers at all projects soon.	All new locks, including 1200' auxiliary chambers, must be economically justified before recommendation can be made for construction.	None
28-1	Supports study and recommendations.	Statement of Support.	None
29-1	Were container ships considered?	Traffic forecasts for this study focused on existing trends. There has been a pilot study for Port of Pittsburgh containers. We did not include containers at this time, but if such traffic develops, future updates of this study take that into account.	None
29-2	River system supports just-in-time delivery, so industry can't wait on a system that's shut down, as well as national security by providing the best way to transport troops and equipment.	Statement of Support.	None
30-1	Supports Corps efforts to keep the system running, noted importance to keeping environmentally compliant coal and stone movements going which in turn allows for provision of reliable electrical service.	Statement of Support.	None
31-1	What is cost breakdown concerning environmental restoration and what are the associated benefits?	There were no estimates of costs or benefits. Instead, a framework of the important issues to be addressed in subsequent studies was identified. (The Ohio River Ecosystem Restoration Program is one vehicle by which these studies may occur.)	None
31-2	Is the restoration part of work associated with locks?	The ecosystem restoration could be accomplished separate from work at the locks.	None

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Comment #	Comment	Response	Revised Section
31-3	Why do bottom lands need to be converted to hardwoods and wetlands restored? Land conversion should be on a voluntary basis.	Conversion of bottom lands to hardwood forests or wetlands was identified by the group of experts convened to determine high priority ecosystem needs. Much of these habitats have been converted to other uses through the years. There is no implication in the report that such conversions would be on a non voluntary basis.	None
31-4	Were impacts on agriculture considered in association with conversion of bottom lands?	We recognize that conversion of bottom lands would likely affect some agricultural lands.	None
32-1	Suggests that the Corps implements any ecosystem restoration program rather than turning over such responsibility to state or local governments.	Implementation of ecosystem restoration is envisioned to be a collaborative effort involving many organizations and individuals regardless of which organization leads the effort.	None
33-1	Was control of riverbank erosion considered as part of the ecosystem restoration program?	Yes, riverbank erosion is one of many sources of riparian habitat degradation that resulted in the need for restoration.	None
34-1	Noted that there is a sharp drop-off, about 4-5 feet out in the Emsworth Back Channel, near Montour Run, directly across from a dock.	Noted on Phone. Will put on mail list for Upper Ohio Feasibility Study.	None

SECTION 12
CONCLUSIONS AND RECOMMENDATIONS

1. Study Conclusions. From the engineering, economic, and environmental analyses preformed for this study, the following conclusions can be drawn:

The Ohio River mainstem is an important natural resource to the nation and is the backbone of the Ohio River Navigation system which together with its six navigable tributary rivers provides efficient water transportation for a vast portion of the Nation. Annually, more than 240 million tons of coal, stone, grains, ores, steel and other commodities move on the Ohio River mainstem. There are 57 coal-fired generating plants on the river which provide 20 percent of the nation's coal-fired electric generation capacity. The Ohio River's navigation infrastructure with main chamber average age of 42 years is essential to the national and regional economy and provides recreation opportunities as well as environmental amenities. The Ohio River is a critical artery of commerce through which billions of dollars of savings are realized by businesses and consumers.

- Each of the traffic scenarios studied are reasonable assumptions of future navigation conditions. The actual future traffic demand will likely be somewhere within the range encompassed by the scenarios and is expected to be reasonably similar to one of them. All of the scenarios studied show increases in navigation traffic in the study period.

- At the present time, 25 percent of locks on the Ohio have exceeded their design life. Within 10 years, 50 percent of the locks will be beyond their original design. Operation and Maintenance funding at the level required for a reactive maintenance scenario has a benefit to cost ratio ranging from 22.7 to 24.6:1. This study also clearly shows the prudence of performing proactive maintenance to include both component replacements and major rehabilitation to provide reliable navigation on the Ohio River mainstem. Such maintenance would provide national economic development benefits of hundreds of millions of dollars annually over and above the benefits achieved through reactive maintenance. The benefit cost ratio for the WPC ranges from 7.8 to 12.7:1.

- No additional authorities are necessary at this time to address the needs related to the reliability of the locks. Follow-on studies are needed for several major rehabilitations and lock improvements.

- The need for early construction of new main locks at the three upper Ohio River locks is apparent across all traffic forecast scenarios. An Upper Ohio Navigation Study is underway.

- Minor repairs and small jobs associated with routine maintenance would cause only localized and limited effects on the ten VECs evaluated in the cumulative effects analysis. Routine maintenance, scheduled maintenance, and an N-Up/N-Down lockage policy would be expected to reduce tow queuing prior to passage through the locks, and to facilitate tow movement through the locks in a timelier manner and thus provide beneficial impacts (effects) on several VECs. Such beneficial effects would result from reductions in localized water turbidity levels; decreases in habitat disturbances for fish, mussels, and riparian resources; lowered accident potentials; and improved recreation opportunities.

- High priority ecosystem sustainability measures are needed for the Ohio River, its tributaries and its associated natural resources on a large scale. These include habitat protection and restoration, control of exotic species, reintroduction of native species, improved connectivity of habitats, and reduction of sources of degradation. These measures are needed to help improve sustainability of many resources including mussels and riparian/floodplain habitats and the species they support.

- The conduct of this study was assessed in accordance with the seven Corps of Engineers Environmental Operating Principles and was found to be consistent with all of them.

- The Lock Modernization Alternative would result in lesser cumulative effects than the other plans. Reduction of cumulative effects would be a positive contribution to sustainability of water quality, fish, mussels, riparian resources, recreation, and health and safety.

- The Cumulative Effects Assessment indicated that future navigation investments would not adversely impact long-term resource sustainability. However, mussels and riparian/floodplain resources are not expected to become fully sustainable in the future due to continued degradation from previous actions combined with the future actions identified.

2. Study Recommendations. The ORMSS SIP is not seeking Congressional Authorization for any new construction projects. Rather, it is a long term planning tool for decision makers in the budgeting and asset/infrastructure management process. It encompasses the entire Ohio River mainstem lock navigation system to optimize funding requirements for anticipated construction, normal operation and maintenance, maintenance and rehabilitation needs. The ORMSS SIP recommendation for the combined plan, which is also the environmentally preferred plan, follows. The annual costs for the SIPs over the period 2010 to 2030 are shown in **Table 12-1**.

Table 12-1
Annual Costs of Optimal SIP Actions,
By Scenario Over Time Period 2010 to 2030
($ Millions)

Year	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
2010	237.87	237.67	238.25	237.45	237.43
2011	124.76	134.59	135.39	127.90	134.41
2012	107.97	111.76	112.67	108.67	111.78
2013	92.95	95.83	95.75	100.90	95.94
2014	231.80	280.39	216.65	285.21	281.20
2015	292.74	295.82	320.75	289.95	294.27
2016	292.61	295.95	323.06	295.10	299.68
2017	152.21	100.12	205.62	101.66	95.86
2018	91.01	101.02	96.56	106.10	91.00
2019	72.95	84.09	73.13	85.60	78.40
2020	72.27	79.11	74.84	80.00	76.83
2021	78.02	73.38	79.94	73.32	73.40
2022	73.59	64.86	69.22	64.80	67.12
2023	67.55	66.20	66.85	66.13	68.46
2024	56.24	55.09	55.35	55.01	56.73
2025	69.22	66.38	62.18	64.39	62.23
2026	69.70	57.68	59.92	57.59	57.69
2027	78.33	68.10	68.76	68.26	61.86
2028	63.57	64.78	63.70	62.40	71.40
2029	71.51	66.54	64.39	66.27	79.29
2030	74.44	66.18	73.36	71.70	74.93

Specific recommendations are:

- Increase Operation and Maintenance (O&M) investments to maximize economic efficiency by realizing the replacement and major rehabilitation of major components when economically justified. Complete all authorized navigation improvements; Olmsted, JT Myers, Greenup, Lower Monongahela, Kentucky Lock and Chickamauga.

- Provide optimal funding for the Upper Ohio River Study currently underway in order for this project to be included in a WRDA in the FY 2010 time frame.

- Initiate main chamber rehabilitation studies for Meldahl, Hannibal, and Myers as soon as possible.

- Initiate main chamber rehabilitation study for Pike Island in the near term (before 2015)..

- Pursue planning and implementation of measures to improve environmental sustainability in collaboration with other interests.

- Initiate preparation of the Program Implementation Plan for the Ohio River Ecosystem Restoration Program.

- Incorporate all Reasonable and Prudent Measures into the Operation and Maintenance of the river.

- Complete work on the Markland gates as soon as possible. Funds provided in FY 2006 will initiate design and continued funding in FY 2007 and beyond will be used to construct the gates and place them in service.

- All detailed evaluation of site-specific impacts for follow on studies and other actions would be tiered from the SIP/PEIS.

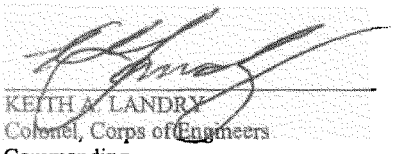
- Initiate the Ohio River Basin Comprehensive Study in order to assess water resource opportunities throughout the basin in collaboration with other interests. Planning efforts should include identification and evaluation of opportunities to improve environmental sustainability throughout the basin including the tributaries.

- Establish a stand alone program (Ohio River Navigation System Investment Program) to update the data and models used in preparing the System Investment Plan. Expand the program capability to include the Ohio River dams and include tributary (Allegheny, Monongahela, Kanawha, Green, Tennessee and Cumberland Rivers) locks and dam structures to support navigation investment decisions and manage future system risk. Use these tools in annual budget formulation.

- Use the Ohio River Navigation System Investment Program to reexamine the medium and long term needs identified in the SIP to optimize investments on these projects.

- All detailed evaluation of site-specific impacts for follow on studies and other actions would be tiered from the SIP/PEIS.

- The System Investment Plan was not developed considering a constrained federal budget or considering the total Ohio River System. Follow on actions need to be conducted to analyze investment strategies with a constrained federal budget and expanded to include all navigation locks, dams and channels on the Ohio River and its navigable tributaries.



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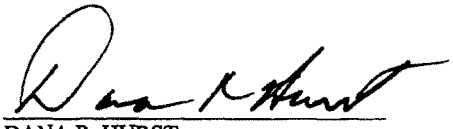

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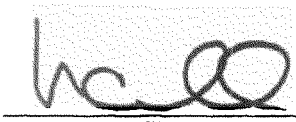

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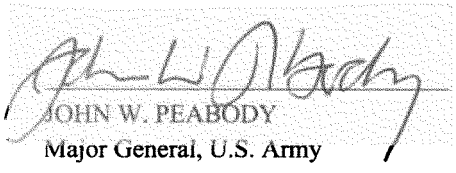

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SECTION 13
LIST OF PREPARERS

The following people were primarily responsible for preparing the Programmatic Environmental Impact Statement:

Name	Discipline/Expertise	Experience	Role in Preparing PEIS
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Mr. David M. Rieger	M.P.A. Public Administration/ B.L.A. Landscape Architecture/ B.S. Environmental Studies	12 years, NEPA Compliance, Pittsburgh and Huntington Districts	Environmental Team Member, Contracting Lead
Mr. Peter K. Dodgion	B.S. Environmental Science/Ecology	13 years NEPA Compliance, Huntington District	Environmental Team Member
Ms. Amy Frantz	M.S. Environmental Science, B.S. Geology	10 years environmental consultant, 5 years	Environmental Team Member

Name	Discipline/Expertise	Experience	Role in Preparing PEIS
		Planning/NEPA Huntington District	
Ms. Janet Cote	M.S. Marine Science/ B.S. Zoology	5 years, Water Quality, Huntington District	Preparation of NAVPAT Report
Mr. Ray D. Hedrick	B.S. Wildlife Biology	3 years Natural Resources Management, 29 years Environmental Planning/NEPA studies, Nashville District	Independent Technical Review
Ms. Deborah Campbell	B.A. & M.A. Anthropology	8 years Pittsburgh District Archeologist; 24 years cultural resource management.	Programmatic Agreement
Woolpert Inc.			
Mr. Eric Hollins	MA Political Science, Environmental Policy BA Political Science	25 years, NEPA compliance	CEA Report, PEIS support
Ms. Lorna Harrell	MS Zoology/Limnology BA Zoology/Science Teaching	25 years, NEPA compliance	CEA Report, PEIS support
Dr. Larry Canter, PE	Ph.D. Environmental Health Engineering MS Sanitary Engineering BE Civil Engineering	38 years, NEPA compliance, methodologies, teaching, ground water hydrology	CEA Report, PEIS support
Mr. Michael Koryak	MS Biology	30 years, environmental	CEA Report, PEIS

Name	Discipline/Expertise	Experience	Role in Preparing PEIS
	BS Biology	sciences & biology, Pittsburgh District (retired)	support
Mr. Warren High	MS Environmental Management BS Fisheries/Wildlife Biology	23 years, NEPA compliance & permitting, stream restoration	CEA Report

GLOSSARY
OHIO RIVER MAINSTEM SYSTEM STUDY/PROGRAMATIC ENVIRONMENTAL IMPACT STATEMENT

Measure — action designed to address problems or needs that can be implemented as part of an alternative.

Alternative — set of measures implemented at various times throughout the planning period to address problems and needs.

Cumulative Impact — the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what governmental agency or person undertakes such actions.

System Investment Plan — Master plan or timetable for implementing maintenance of major lock and dam components, non-structural efficiencies and low-cost structural measures, and establishing budgets for future major rehabilitation and lock modernization feasibility studies for Ohio River navigation projects. These activities would supplement routine or day-to-day maintenance and cyclic maintenance activities that are required to keep any navigation facility operational. Major rehabilitation studies would be required for costly maintenance projects meeting requirements for that program. Feasibility studies would be required for Congressional authorization of the construction of larger locks. This plan also addresses high priority ecosystem needs for the Ohio River.

ITR — Independent Technical Review, a procedure followed by the Corps to ensure overall quality of a variety of products ranging from planning studies to construction projects. All ITRs involve review by qualified independent personnel not affiliated with the development of the product being reviewed for the purpose of confirming the Corps studies are done in accordance with clearly established professional principles, practices, codes and criteria.

Environmental Sustainability — capability of remaining in a healthy and viable state for future generations. ES is identified in the Corps' recently published Environmental Operating Principles as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations" (U.S. Army Corps of Engineers, 2002).

Valued Environmental Components — significant environmental resources based on political, legal, public, and professional significance considerations. The following ten VECs were identified for the Ohio River: 1) water and sediment quality, 2) fish, 3) mussels, 4) riparian and floodplain resources, 5) health and safety and 6) river-based recreation, 7) air quality, 8) transportation and traffic, 9) socioeconomics and 10) cultural resources. The first six of these were considered more significant and received greater emphasis in the environmental sustainability analysis.

Ohio River Ecosystem Restoration Program — Authorized by the Water Resource Development Act of 2000, this program would identif3' and prioritize ecosystem needs for the Ohio River corridor consistent with current law and Corps policy. Non-Federal sponsors would fund *35* percent of site-specific project first costs and 100 percent of operation, maintenance, repair, rehabilitation, and replacement. Projects would be designed by a partnership composed of representatives from government resource agencies, universities, and other environmental concerns. This program would involve monitoring, evaluating and managing the Ohio River ecosystem. A corridor-wide ecosystem needs assessment and strategy, or Program Implementation Plan, would be developed initially to refine ecosystem goals and prioritize restoration efforts. As of the date of this report, this program has not been funded.

Programmatic Environmental Impact Statement — one type of environmental documentation stipulated by Council of Environmental Quality regulations that can be used to assess the implications of policies and programs of federal agencies or actions that are similar in nature or broad in scope.

National Economic Development Plan — that plan that reasonably maximizes the economic value to the nation consistent with sound environmental design principles.

National Ecosystem Restoration Plan — that plan that reasonably maximizes ecosystem quality of environmental resources under consideration in a cost effective manner.

National Ecosystem Sustainability Plan — that plan that reasonably ensures ecosystem sustainability of environmental resources under consideration in a cost effective manner.

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US Army Corps
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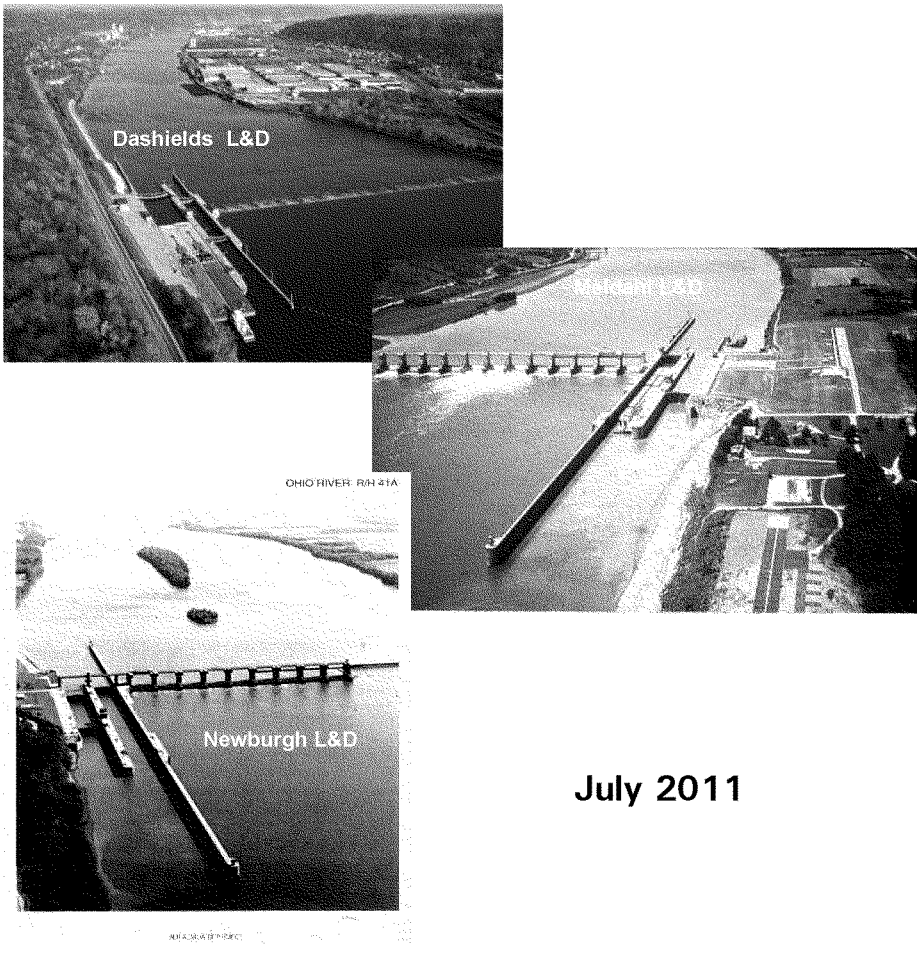
Great Lakes and Ohio River Division
LOUISVILLE DISTRICT / HUNTINGTON DISTRICT / PITTSBURGH DISTRICT

Ohio River Mainstem Systems Study (ORMSS)

System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Engineering Appendix and Economics Appendix



July 2011

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
P.O. BOX 59
LOUISVILLE, KENTUCKY 40201-0059

System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Engineering Appendix

July 2011

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List of Acronyms

ATC	Average Towing Cost
BEA	Bureau of Economic Analysis
BTU	British Thermal Unit
CAAA	Clean Air Act Amendments
COE	Corps of Engineers
CR	Component Replacement
DOE	Department of Energy
EDM	Emsworth, Dashields and Montgomery
EIA	Energy Information Administration
EQ	Equilibrium Model
ER	Engineering Regulation
HQ	Headquarters (Corps)
IWR	Institute for Water Resources
L/D	Lock(s) and Dam
LPMS	Lock Performance Monitoring System
LRD	Great Lakes and Ohio River Division
LRM	Lock Risk Module
MRS	Marginal Rate Savings
MTC	Marginal Towing Cost
NAAQS	National Ambient Air Quality Standards
NAVPAT	Navigation Predictive Analysis Technique
NED	National Economic Development
NER	National Ecosystem Restoration
ODC	Origin-Destination-Commodity
O&M	Operation and Maintenance
OM	Optimization Module
ORB	Ohio River Basin
ORMSS	Ohio River Mainstem Systems Study
ORNIM	Ohio River Navigation Investment Model
ORNL	Oak Ridge National Laboratory
ORS	Ohio River System
P&G	Principles and Guidelines
PMP	Project Management Plan
PRB	Powder River Basin
RM	Reactive Maintenance
SIP	System Investment Plan
TCM	Tow Cost Model
TVA	Tennessee Valley Authority
USACE	US Army Corps of Engineers
WAM	Waterway Analysis Model
WCSC	Waterborne Commerce Statistical Center
WOPC	Without-Project Condition
WPC	With-Project Condition
WSDM	Waterway Supply Demand Module

Section 1

INTRODUCTION TO ENGINEERING APPENDIX

1.1 PURPOSE OF THE ENGINEERING APPENDIX

The Ohio River Mainstem Systems Study (ORMSS) Engineering Appendix is intended to give the reader a detailed overview of the multiple engineering features associated with this study. An overview of the ORMSS System Investment Plan (SIP) and the purpose of the study are provided in the ORMSS Main Report. The reader is referred to the Main Report to learn more about that type of information. There were many technical engineering features associated with the analysis of the SIP, such as Without Project O/M costs, analytical reliability models for critical components, probabilistic analysis supporting the determination of major rehabilitation needs, and conceptual With Project designs and costs estimates for select, larger-scale projects such lock extensions of auxiliary chambers and new lock chambers. There are four primary features of the ORMSS Report: Environmental, Engineering, Economics, and Plan Formulation. Engineering is fully integrated with each of the other aspects of the study and this appendix details both the supporting analyses as well as information provided as it relates to the overall economic analysis.

A historical perspective on the Ohio River in terms of navigation is provided in Section 2 of this appendix. Information in this section focuses on the effort to provide year round navigation on the Ohio River with the earliest efforts of canalization. There is also a summary of the original set of intermediate, or low-lift locks and dams, along the Ohio River. Finally, the modernization effort which converted many low-lift locks into a lesser number of high-lift locks is also described in Section 2 of this appendix.

Information regarding pertinent prior studies, including the ORMSS Interim Report (approved in 2000), is summarized in Section 3 of this appendix. This section also provides an excellent review of how the ORMSS was initiated through studies of lock expansion at the former Uniontown Locks and Dam (renamed John T. Myers Locks and Dam in 1996).

Section 4 of this Engineering Appendix gives an overview of the existing configuration of the mainstem of the Ohio River navigation system. It includes a site-by-site description of each lock chamber including an aerial photograph of the project, as well plan view and site map. In addition, a brief overview of the existing condition of the structure and assessment of needs is provided for each site.

Probabilistic engineering reliability analysis is detailed in Section 5. This section covers the process by which the components requiring advanced modeling were determined through a two-phase ranking system. A detailed description of the finite element modeling and subsequent reliability analysis for miter gates and culvert valves is

provided in this section as well. Other modeled components (lock walls, mechanical systems, and electrical systems) are also detailed in this section. Finally, the expert elicitation for mass concrete deterioration at upper three Ohio River project, Emsworth, Dashields, and Montgomery (EDM), is described as well.

Section 6 of this appendix covers project specific cost and closure schedules for maintenance. This includes maintenance dewatering schedules and costs for the Pittsburgh, Huntington, and Louisville Districts as they relate to each project. The major differences between each district's costs and procedures are outlined.

The final section of the Engineering Appendix provides information regarding conceptual With Project designs and cost estimates for expansion of lock capacity at sites determined to be potential candidates for such improvement. Note that the With Project lock capacity expansion designs and cost estimates are conceptual in nature since the final ORMSS Report is not actually authorizing any project for large scale construction, therefore, traditional "feasibility-level" designs and costs are not applicable for this report. This is a change from the last ORMSS Report (Interim Report) in 2000, which was used to authorize lock capacity improvement construction at two high priority sites. If an individual site appears to have economic merit regarding potential lock capacity expansion, the individual district will need to secure funds to initiate feasibility-level designs, estimates, and go through the appropriate congressional approval process.

1.2 PRIOR STUDIES AND REPORTS RELATED TO ORMSS

In Fiscal Years 1990-91, funds were appropriated for an Interim Reconnaissance Report for Uniontown Lock and Dam (now John T. Myers Locks and Dam). The J.T. Myers project is located in the lower reaches of the Ohio River, about 30 miles downstream of Evansville, Indiana -- just upstream of the mouth of the Wabash River. The Uniontown Recon Study focused on only this one lock site, and in June 1991 a Recon Report was issued, which found positive benefits for traffic-capacity expansion at the Uniontown site. USACE Headquarters' review of this Reconnaissance Report, dated 14 February 92, stated:

> The Corps must take a "systems look" to properly address the level of investments needed to continue to provide a viable navigation system ***on the Ohio River Mainstem***. ... the entire Ohio River Mainstem navigation system should be carefully reviewed, but your primary emphasis for this study should concentrate on the lower portion of the river.

Table ED 1-1 summarizes documents pertinent to the ORMSS, particularly those relevant to the ORMSS Interim Report, which was completed and approved in FY 2000. The ORMSS Interim Report authorized two major navigation projects, the J.T. Myers Locks Improvements Project and the Greenup Auxiliary Lock Extension Project, as well as a Systematic Environmental Restoration Project. All of these were authorized with the Water Resources Development Act (WRDA) of 2000.

Table ED 1-1. List of Prior Studies and Related Reports

Document Title	Date	Produced by	Summary	Conference or Reference	Disposition / Status
Information Brochure for Periodic Inspection, Uniontown L&D	Jun-74	CELRL-ED	Reference data used for periodic inspections of the L&D facilities.	not applicable	Includes "as-built" drawings for Uniontown L&D (now Myers L&D). Constructed June 1965- Sept 1972.
Final Technical Report H-75-6 Navigation Conditions at Cannelton L&D, Ohio River	Apr-75	CEWES-HS	Pre-construction hydraulics model investigation for Cannelton L&D -- replaced old L&D's 43-45 w/1-1200 ft lock & 1-600 ft lock + 1365 ft of gated, non-navigable dam	not applicable	Uniontown L&D is 1 of 5 new L&D's (circa 1965) to replace 11 old navigation structures on the Ohio R.
Final Technical Report H-75-9 Navigation Conditions at Uniontown L&D, Ohio River	May-75	CEWES-HS	Pre-construction hydraulics model investigation for Uniontown L&D -- replaced old L&D's w/1-1200 ft lock & 1-600 ft lock + gated spillway and fixed overflow dam	not applicable	
Ohio River Mainstem Nav Study Interim Reconnaissance Study Uniontown Locks & Dam	1-Jun-91	CELRL-PDF	Evaluated large scale improvement alternatives	Recon Review Conference., Louisville 17 Sept 91	CECW-PE review memo of 14 Feb 92. Recon eventully certified per acceptance of P.S.P. in June 96.
Uniontown / ORMS LowCapitalCost Lock Alternatives (DACW27-92-D-0010)	29-Jan-93	HARZA Engrs, (Chicago, IL) for CELRL-ED-DS	Discussed alternatives for different lock components: 6 different walls, 6 gates, 5 empty-fill systems.	Plan Formulation / ED-D coordination. 1st step in low-cost alternatives' design.	Led to later delivery orders by HARZA for layouts at Uniontwn, Newburgh, Cannelton.
Uniontown Locks & Dam/ Ohio River Mainstem Study Initial Project Mgt Plan (IPMP)	1-May-93	CELRL-PDF	Outlined a $10M study, focusing on Uniontn, Newbrgh, & Cannltn Lks, to be complete in 1997.	CECW-P / ORD staffs meet, 10Dec93. IPMP apprvd 7Jun93 by ORL Proj. Mgt. Board.	CECW-PD draft review memo of 6 Jan 94, called for broader scope, includg: (1) itemize all Mainstem nav.costs (long-term); (2) detailed Risk assessmt.
ORMSS Design & Cost Screening of Lock Expansion Alternatives - Uniontown L&D (Final Report)	Jan-95	HARZA Engrs, (Chicago, IL) for CELRL-ED-DS	Evaluated low-cost lock expansion alternatives (including extending the 600-ft lock + low-cost methods to construct a new 1200-ft lock)	Final submittal, Delivery Order 0002, DACAW27-92-D-0010	Led to alternatives per later INCA contract.
Ohio River Mainstem Systems Study, Project Study Plan (PSP) [submittal # 1]	16-Jun-95	CELRD-wide team, edited: CELRL-PDF	Outlined $48M study of entire Main Stem, complete in 2002. Assumes full Feasibility detail for 9 sites.	ORD / CECW staffs, Aug95. Briefed Dir CW, Sep95. Certified 16Jun95, by ORD team leaders & Commanders.	CECW memo 13 Oct 95
ORMSS Design & Cost Screening of Lock Expansion Alternatives - Cannelton L&D (Final Report)	July-95	HARZA Engrs, (Chicago, IL) for CELRL-ED-DS	Evaluated low-cost lock expansion alternatives (including extending the 600-ft lock + a low-cost method to construct a new 1200-ft lock)	Final submittal, Delivery Order 0003, DACAW27-92-D-0010	Led to alternatives per later INCA contract.

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Table ED 1-1. List of Prior Studies and Related Reports (continued)

Document Title	Date	Produced by	Summary	Conference or Reference	Disposition / Status
ORMSS Design & Cost Screening of Lock Expansion Alternatives - Uniontown L&D (Final Report)	July-95	HARZA Engrs, (Chicago, IL) for CELRL-ED-DS	Evaluated low-cost lock expansion alternatives (including extending the 600-ft lock + a low-cost method to construct a new 1200-ft lock)	Final submittal, Delivery Order 0004, DACAW27-92-D-0010	
ORMSS DRAFT Project Study Plan (PSP) [submittal # 2]	1-Feb-96	CELRD-wide team, edited: CELRL-PDF	Outlines $37M study, to be complete in 2000. Costs assume full Feasibility-detail at equivalent of 5 sites.	Fig.4-1 and study outline per discussion w/ CECW-P, 12Dec95 at LexingtonKY	More detail / organization: specific tasks and goals clearly shown. Differentiation between "early action" and other study efforts.
Revised June 96 Project Study Plan (PSP) [submittal # 3]	1-Jun-96	CELRL-PDF	Similar to Feb 96 PSP in terms of overall schedule and costs, but with "Lower River" early actions removed.	CEORD memo to Dir. of Civil Works, HQUSACE, 10Apr96	Lower River "early-action" initiatives removed--new innovative designs allow "in-water" construction with minimized traffic delays.
ORMSS Workshop Documentation, March 18-22 1996, DACW27-95-C-0126	11-Jun-96	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	Results of week-long workshop. Includes PRELIM costs for various lock components.	ORMSS engineers' workshop, Bellevue, 18-22 Mar 96	"Jumpstart" to INCA-Corps collaboration on ORMSS designs
Ohio R. Navigation System Report, 1996 COMMERCE ON THE OHIO RIVER AND TRIBUTARIES	1996	CELRH-NC	The Biennial Report of Commerce and a system-wide inventory of facilities on the Ohio River and its tributaries	not applicable	This color , 20+ page brochure is updated every 2-3 years, with an annual stats update other years.
ORMSS Design Presentation for the 600 C-1 600-ft Lock Extension Alternative (DACW27-95-C-0126)	Mar-98	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	Handout for presentation of to team engineers -- nine different empty-fill configurations	Document prepared for presentation to the ORMSS design/formulation teams at CELRL on 10-11 March 1998.	Handout for presentation of to team engineers -- nine different empty-fill configurations
ORMSS Workshop Documentation, Supp. #1: Alternative 600C Report August 29, 1996, DACW27-95-C-0126	Aug-96	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	Plan 600C utilizes various elements: Float-in gate bay and lock wall monoliths, split lateral fill/empty system with outlet diffuser, floating approach walls	Supplement to workshop documentation for an additional Plan 600-C, developed following the workshop of Mar 96	
ORMSS Workshop Documentation, Supp #2: Alternative 600D Report September 27, 1996, DACW27-95-C-0126	Sep-96	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	Plan 600D utilizes various elements: Float-in gate bay and lock wall monoliths, split lateral fill/empty system with outlet diffuser, floating approach walls	Workshop documentation for an additional alternative, 600-D, developed following the workshop of Mar 96	
ORMSS Alternative 600C Adaptation Report October 29, 1996	Oct-96	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	Prelim. effort to adapt Alt 600-C for the Markland, Cannelton & Newburgh L&D sites -- site differences & costs.	not applicable	Useful for final ORMSS report -- Plan 3 adaptions to various sits

TABLE ED 1-1. LIST OF PRIOR STUDIES / REPORTS, ORMSS (continued)

Document Title	Date	Produced by	Summary	Conference or Reference	Disposition / Status
Lock Closure Data Base for Louisville, Huntington & Pittsburgh Districts (Final Report, DACW69--93-D-0017, W.O. 004)	Apr-96	Jack Faucett Associates, Bethesda, MD., for CELRH-NC	Inventoried high-lift lock closures in the Ohio R. system exceeding 8 hrs duration, from 3 different sources of data, w/ statistical analysis, for O&M analyses.	Various Econ/Plan Formulation team members	partial input to Without-Project lock closures' assumptions
Report - ORMSS Prepare Conceptual Design for Emsworth L&D, Ohio R, 100% submittal (DACW57-D-0003, DeLO.# DV01)	Sep-97	INCA Engineers (Bellevue, WA) for CELRP-ED	Explains engr'g drawings (below) for concept level design for adding a 1200' lock at Emsworth L&D, Ohio R.	Various team and Oversight meetings -- first step towards upper Ohio L&D improvement costing.	Useful for final ORMSS report -- Emsworth is one of three old L&D facilities on the upper Ohio River.
Drawings - ORMSS Prepare Conceptual Design for Emsworth L&D, Ohio River, 100% submittal (DACW57-D-0003, DeLO.#DV01)	Sep-97	INCA Engineers (Bellevue, WA) for CELRP-ED	Drawings detail engr'g and concept level design for adding a 1200-ft lock at Emsworth L&D, Ohio R. (See companion report)	" "	" "
Report - ORMSS Prepare Conceptual Design for Montgomery L&D, Ohio River, 100% submittal (DACW57-D-0003, DeLO.# DV03)	Aug-97	INCA Engineers (Bellevue, WA) for CELRP-ED	Document details engr'g drawings for concept level design for adding a second 600-ft or a 1200-ft lock at Montgomery L&D, Ohio R.	" "	Useful for final ORMSS report -- Montgomery is one of 3 old L&D facilities on the upper Ohio River.
Drawings - ORMSS Prepare Conceptual Design for Montgomery L&D, Ohio River, 100% submittal (DACW57-D-0003, DeLO.#DV03)	Sep-97	INCA Engineers (Bellevue, WA) for CELRP-ED	Document details engr'g drawings for concept level design for adding a second 600-ft or a 1200-ft lock at Montgomery L&D, Ohio R.	" "	" "
Report - ORMSS Prepare Conceptual Design of Dashields L&D, Ohio River, 100% submittal (DACW57-D-0003, DeLO.#DV03)	Sep-97	INCA Engineers (Bellevue, WA) for CELRP-ED	Document details engr'g drawings for concept level design for adding a second 600-ft or a 1200-ft lock at Dashields L&D, Ohio R.	" "	Useful for final ORMSS report -- Dashields is one of 3 old L&D facilities on the upper Ohio River.
ORMSS Field Inspection Report of all L&D Facilities on the Ohio River (Pittsburgh, Huntington & Louisville Districts)	1996-1997	CELRP-EDD; inspections by a core group of LRP/ LRH/ LRL engineers.	Details visual inspection of facilities at each L&D plus interviews with Lockmasters & projects' O&M Leaders. Provides numerical ratings for various L&D components, and photos of conditions at each L&D.	Various team and Oversight meetings -- comparative data to begin reliability analyses.	A step in the process of evaluating risk & reliability for the L&D components and facilities throughout the Ohio R. Mainstem system.
OHIO RIVER NAVIGATION SYSTEM -- 1997 Statistical Supplement	1997	CELRH-NC	Intervening-year statistical update to the biennial Ohio R. Nav. System Report (1996)	The publication also references other Waterway Data Publications and their sources as well as a World Wide Web data access site.	Color., 20+ page Nav.Center brochure (see 1996 report listing above)
ORMSS Design Presentation for the 600 C-1 600-ft Lock Extension Alternative (DACW27-95-C-0126)	Mar-98	INCA Engineers (Bellevue, WA) for CELRL-ED-DS	An advanced presentation to team of 9 different empty-fill configurations (per next document below).	Document prepared for presentation to the ORMSS design/formulation teams at CELRL on 10-11 March 1998.	Discussions led to minor revisions in next document (below).

Table ED 1-1. List of Prior Studies and Related Reports (end)

Document Title	Date	Produced by	Summary	Conference or Reference	Disposition / Status
ORMSS - 100% Submittal Constructibility and Cost Estimate (Analyses) for Prototype Alts. *(DACW27-95-C-0126)*	May-98	INCA Engineers (Bellevue, WA) for CELRL-ED	Descriptions, drawings, constructn schedules, & cost estimates for 9 configuratns of F/E systems. Constructibility evaluations.	Report requested by Plan Formulation and ED teams, and incorporates comments received from 10-11 March and District reviews.	Essentially, evaluated sensitivity of layout costs to various empty-fill configuration for both 600 Aux. Extensions, and 3rd lock plans.
ORMSS -Engineering Appendix for Large-Scale Improvements (Prototype Designs) , *DACW 27-95-C-0126*	Jun-98	INCA Engineers (Bellevue, WA) for CELRL-ED	Feasibility-level design (50% complete) based on J.T.Myers site, considered site adaptable to other Main Stem sites	INCA contract requirement: 50% point submittal	on-going development of Myers Engineering Technical Appendix for Interim Report
MANAGEMENT SUMMARY -- Cultural Resources Database Construction for ORMSS *(DACA27-960C-0077)*	Aug-98	Gray & Pape, Cultural Resources Consultants, Richmond, VA for CELRL-PD-E	Summarizes efforts in creating 6 cultural resource database files for portions of 6 states along the Ohio R. mainstem nav. system (PA, WV, OH, KY, IN and IL), and tabulates findings.	Cultural Resources inventories for ORMSS.	Designed to work in coordination with a GIS database established by Gulf Engineers/Consultants (GEC)
REPORTS SPECIFIC to GREENUP LOCKS and DAM					
Greenup Locks and Dam, Ohio River, Design Memo #1, Huntington District, Corps of Engineers	Dec-53	CELRH-ED	General Design Memorandum -- overall layout and design assumptions	NA	Beginning of Post-Authorization design work
Navigation Conditions at Greenup Locks and Dam, Ohio River, Hydraulic Model Investigations, Technical Report #2-469	Jan-58	CEWES-HS for CELRH-ED			
Filling and Emptying System for Greenup and Markland Locks, Ohio River, Hydraulic Model Investigations, University of Minnesota	Jan-62	Univ. of Minnesota Hydraulics Lab for CELRH-ED			
Greenup Locks and Dam Periodic Inspection Report #1	Oct-68	CELRH-EC-DS	Reference data used for periodic inspections of the L&D facilities		Includes "as-built" drawings for Greenup L&D, constructed from 1955 to 1962
Meldahl L&D 600-ft Lock Extension Plan, Recon.Level Screening Study, Final submittal, *DACW69-97-D-0012, D.O.# 0001*	Mar-98	Black & Veatch (Kansas City, MO) for CELRH-EC-DC	Evaluated low-cost lock expansion alternatives		Initial first look at alternatives and cost for a Meldahl 600-ft Lock Extension

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Section 2

OHIO RIVER NAVIGATION SYSTEM – HISTORICAL PERSPECTIVE AND CURRENT STATUS

2.1 HISTORY

2.1.1 Early Settlers and Steamboat Era

The first European explorers to visit the Ohio River Valley are believed to have arrived with De Soto's expedition in 1540. The first pioneers consisted of trappers, fur traders, and soldiers. Canoes provided the most common mode of transportation on the rivers. Over time, the French came to dominate the area with fur trading as their primary economic interest. The increased presence of Euro-American colonial traders by the mid eighteenth century prompted the French to build forts on the Allegheny River in an attempt to reclaim the Ohio River Valley. In 1753, Virginia militiamen, led by Major George Washington, attempted to construct a fort where the Allegheny and Monongahela Rivers combine to form the Ohio River. The French drove them away and built Fort Duquesne instead. In 1758, British forces regained control of the area and replaced Fort Duquesne with Fort Pitt. With the establishment of Fort Pitt, the City of Pittsburgh evolved in the surrounding areas. Because of its strategic location at the head of the Ohio River, Pittsburgh became a major port of embarkation for settlers and commodities traveling west. Flatboats and barges carried the trade of the country downstream. Since flatboats and barges could only travel downstream, the lumber making up these vessels was frequently sold at destination. Keelboats provided the first means for travel both upstream and downstream on the river. They provided regular passenger and freight service between Pittsburgh, Cincinnati, and Louisville. It typically took one month to complete the round trip between Pittsburgh and Cincinnati.

The steamboat era on the Ohio River began in 1811 when the New Orleans departed from Pittsburgh. Early steamboats had deep keels and were not suited for navigation on the shallow western rivers. The development of the first shallow draft steamboat in 1816 set a pattern for the river steamboats which followed. The presence of snags and sandbars, however, plagued navigation. Deadly snags could easily hole out and sink a steamboat without warning. Accidents and fatalities were commonplace. The success of the steamboat and its impact throughout the Ohio River Basin led to the first significant action by the Federal Government to improve navigation conditions.

2.1.2 Improvements to Navigation

When compared to overland routes, the Ohio River provided an easy mode of travel to the west. Travel on the river, however, had its fair share of hazards. In its

original condition, the Ohio River was obstructed throughout its entire length by snags, rocks, and sand bars. Navigation was difficult and hazardous due to extreme variations in channel width and depth. During periods of low water, the depth could be as little as one foot over the worst shoals. This did not provide sufficient depth for vessels to safely navigate the river.

On 24 May 1824, the first Inland Waterways Improvement Act directed that experiments be conducted to determine the best method for dealing with the sandbars and snags that continued to obstruct navigation on the Ohio River. At this time, the primary function of the Army Engineers in the Ohio River Basin was to improve and develop waterway navigation for steamboat commerce.

One of the first obstacles to be addressed was the rapids near Louisville known as the "Falls of the Ohio". The rapids dropped nearly 26 feet and extended for two miles. Navigation over the falls was impossible except during periods of high water. The Louisville and Portland Canal was completed in 1830 allowing river traffic to bypass the falls. The canal was 1.9 miles long and had three successive locks measuring 50 feet by 185 feet. Since completion of the canal, continuous improvements have been made to the project which is now known as McAlpine Locks and Dam.

The development of the double hulled snag boat by Captain Shreve greatly reduced the snag hazard. Snags were large and numerous with some weighing over one hundred tons. Removal of rock in the channel near Grand Chain commenced in 1830. The use of cutoff dams on back channels and wing dikes to concentrate flow in the main channel improved the navigable depth in most areas to a minimum channel depth of three feet. In 1825, the first wing dike was built at Henderson Bar. Dikes were constructed at Scuffletown and Sisters Islands in 1831 and at French and Cumberland Islands in 1832. Improvements upstream of Louisville were limited to snag removal until 1836 when the dams at Brown Island were built. The success of this project led to the construction of many wing dikes and back channel dams between Pittsburgh and Cincinnati. Improvements to navigation continued on a regular basis through 1844. Contrasting political leadership and the Civil War essentially ended all work from 1845 to 1866.

2.1.3 Canalization

In 1835, Lieutenant George Dutton first expressed his view that the construction of locks and dams was necessary to provide adequate navigation conditions for year round use of the Ohio River. The idea was overlooked at first due to the magnitude of the engineering problems to be dealt with and objections of the river users who believed that dams would be a hindrance to navigation. This attitude began to change during the mid nineteenth century when one way flatboats used to transport coal to downstream destination points were gradually replaced by steamboats towing fleets of coal barges downriver and returning with the empty barges for reuse. It soon became apparent that a system of locks and dams was needed to accommodate the growing coal fleets. Construction of thirteen locks and movable dams between Pittsburgh and Wheeling was proposed by Major W. E. Merrill in 1874. The proposed system was an essential part of the plan to provide a 6-foot navigable depth on the upper Ohio River.

The concept of a movable dam was adopted to meet the needs of coal boat operators. The dam could be raised during low flows to maintain a harbor pool and lowered during high water to allow passage of the coal boat fleets without lockage. The

movable wicket dam invented in 1852 by Chief Jacques Chanoine of the French Corps of Engineers was adapted to meet the needs of the Ohio River. The wickets consisted of a set of timbers that were bolted together. During high water they lay flat against a masonry foundation leaving an open channel for navigation. At low water, the wickets were raised on end to form a dam.

The River and Harbor Act of 1875 provided funds for the construction of a movable dam 4.7 miles downstream of Pittsburgh at Davis Island. The original goal of the project was to provide a pool at Pittsburgh for assembling of coal boats and formation of tows suitable for the downstream run when a "coal boat rise" occurred on the river. Work began in 1877 and the structure was opened to traffic on 7 October 1885. Since it was the first canalization project on the Ohio River, the Davis Island Dam became known as Dam 1.

The Davis Island Dam was 1223 feet long with a Chanoine wicket pass of 559 feet and three Chanoine weir sections. The back channel of the Ohio River was closed with a non-navigable stone-filled timber-crib dam. Because of ice conditions typically experienced on the Ohio River, the wickets in the navigable pass were raised and lowered with a maneuver boat. A service bridge was used to raise and lower the weir wickets. Damage to the bridge by barges and debris led to the use of a maneuver boat for raising and lowering all of the wickets. A drift gap was also added in 1889 to pass floating logs and other debris. Fortunately, the difficult task of raising and lowering the wickets occurred at infrequent intervals during very low or high water.

The 110 foot wide by 600 foot long lock at Davis Island was designed to meet the needs of the coal boat fleets. These dimensions became standard for the initial canalization of the entire Ohio River. The lock chamber was closed via rolling gates mounted on wheels. A recess in the landward lock wall provided storage for the gates.

A consecutive numbering scheme was used to denote the next four dams that were constructed downstream of Davis Island Dam (Dam 1). Appropriations for these projects were made by various River and Harbor Acts starting in 1890. Dam 2 was located 9.0 miles downstream of Pittsburgh and was constructed between 1898 and 1906. Construction of Dam 3, located 10.9 miles from Pittsburgh, occurred between 1899 and 1907. Dams 4, 5, and 6 were built between 1892 and 1908 at miles 18.6, 24.1, and 29.3, respectively.

The board of Engineer officers designated by the River and Harbor Act of 1902 recommended that the navigable depth in the upper Ohio River be increased from six to nine feet. Appropriations for modifications to Dams 2-6 came from the River and Harbor Act of 1905. By 1906, a proposal for a nine foot navigation depth for the entire Ohio River was approved for implementation. The formal authorization for the nine foot depth was provided by the River and Harbor Act of 1910. The original plan called for a total of 54 locks and dams. The projects were divided among four Engineer Districts: Pittsburgh (Dams 1-10), Wheeling (Dams 11-28), Cincinnati (Dams 29-40), and Louisville (Dams 41-54). Of the fifty four dams originally envisioned, only fifty one were included in the final plan. Dams 40, 42, and 54 were eliminated by modifying other projects. The dams had a navigable pass that could be used during high water and a single 110- by 600-foot lock chamber that could be used the remainder of the time.

Upon completion of a reexamination study of the Ohio River in 1916, it was recommended that fixed dams replace the movable wicket dams. The Emsworth Locks and Dams at mile 6.2 replaced Dams 1 and 2. This was the first time that the concept of

movable wicket dams was abandoned in favor of a non-navigable concrete dam. To avoid traffic delays caused by lock closure, two locks were built at the site. The main lock was 110- by 600-feet and the auxiliary lock was 56- by 360-feet. Upon its completion in 1921, the project provided the first non-navigable dam and first twin locks on the Ohio River. In addition, the non-navigable Dashields Locks and Dam was built as a replacement for Dam 3 at mile 13.3. The configuration of Dashields was similar to that of Emsworth. Initial canalization of the Ohio River was finally completed in 1929. Of the fifty lock and dam structures, all but two had a navigable pass.

2.1.4 Intermediate Projects

Following canalization of the Ohio River, several intermediate projects were constructed to enhance navigation conditions. These projects were built prior to the modernization era which began in 1953.

The 56- by 360-foot auxiliary lock chamber at Locks and Dam 41 was completed in 1930. The additional lock substantially increased the capacity of the project. The Emsworth Dams were reconstructed between 1935 and 1938 with gated crests. The upstream pool was raised by seven feet and two lock and dam structures were eliminated.

The storage of water in Tygart Lake, completed in 1938, provided sufficient flows for navigation on the upper Ohio River during dry periods. The project is also part of the comprehensive Ohio River flood control system and provides for water supply and pollution control.

Two new navigation projects were also constructed during this period: Montgomery Locks and Dam in 1936, and Gallipolis Locks and Dam in 1937. Montgomery Locks and Dam, located at mile 31.7, replaced Dams 4, 5, and 6. With a lift of 17.5 feet, it was the first high lift project completed on the Ohio River. The project had two locks measuring 110- by 600-feet and 56- by 360- feet. The Gallipolis Locks and Dam at mile 279.2 replaced three dams on the Ohio River and three on the Kanawha River. It was the most modern lock and dam project of its time. Both locks were 110 feet wide with lock lengths of 600 feet and 360 feet. The original purpose of the Gallipolis project was to improve navigation conditions on the Kanawha River; however, it is operated as part of the Ohio River system. By replacing six existing locks and dams, the Gallipolis Locks and Dam reduced operation and maintenance costs. In addition, the movement of river traffic was expedited as a result of fewer lockages. After completion of the Gallipolis project, there were forty one movable wicket dams and five non-navigable dams on the Ohio River.

2.1.5 Modernization

River traffic on the Ohio River declined during the Great Depression but resumed its climb soon afterward. The original system of locks and dams, designed to transport 13 million tons annually, was moving nearly 38 million tons by 1942. Traffic had increased dramatically and tow lengths of 1000 feet had come into widespread use. The 600-foot lock chambers became obsolete in the early 1950s and, in some cases, became an impediment to the navigation they were designed to enhance. It became evident that a smaller number of high lift locks and dams with longer navigation pools would be needed to improve the system. A full scale modernization program began in 1953. The program

provided for the progressive replacement of low lift navigable structures with a smaller number of non-navigable structures with higher lifts. The nine foot navigation channel depth continued as the standard, but lock chamber sizes were increased to accommodate the larger tows. According to river users, a 110- by 1200-foot lock could accommodate the largest tows that could be efficiently operated on the Ohio River. The Corps adopted these dimensions for the main lock chambers at all new projects. In addition, a 110- by 600-foot auxiliary lock chamber was to be provided to improve dependability, flexibility, and capacity.

Construction priority for the new projects was based on the traffic demands of the time. The first modernization project, New Cumberland Locks and Dam, was completed in 1959. Structures at Greenup, Meldahl, and Markland soon followed. By 1979, a total of thirteen new high lift structures had been built to replace thirty nine low lift locks and dams. The new projects had lifts from 16 to 35 feet and pools with an average length of 59 miles. This was a significant improvement over the old structures which had lifts of 5 to 11 feet and pool lengths less than 20 miles. All of the new projects had a 110- by 1200-foot main lock chamber and a 110- by 600-foot auxiliary lock chamber. The only exception is Smithland Locks and Dam which had twin 110- by 1200-foot lock chambers. In addition to the new construction, a 1200 foot lock was built at McAlpine in 1967 to meet the demands of increased traffic. The existing locks at Gallipolis Locks and Dam (renamed R. C. Byrd Locks and Dam) were replaced with a 110- by 1200-foot main lock and a 110- by 600-foot auxiliary lock in 1993. An additional 1200-foot lock chamber is now under construction at McAlpine to replace the inadequate 600-foot auxiliary lock. Only two of the original locks and dams (52 and 53) remain today. They are scheduled to be retired when the last replacement project of the modernization program, Olmsted Locks and Dam, is completed. The Olmsted project will have twin 110- by 1200-foot lock chambers. The dam will also incorporate movable steel wickets that will allow free movement of traffic during periods of moderate to high flows.

2.2 EXISTING LOCK HYDRAULICS CHARACTERISTICS

Table ED 2-1 was developed to provide basic information about the existing eighteen locks and dams on the Ohio River and the Olmsted Locks and Dam presently under construction to replace Locks 52 and 53. Note that the authorization of auxiliary lock chamber extensions at John T. Myers and Greenup will change those project configurations once construction is completed. Both projects are currently undergoing final design and initial construction of support facilities has started on J.T. Myers at the time of this report.

Table ED 2-1. Ohio River Project Characteristics

	EMSWORTH	DASHIELDS (Dead Man's Island)	MONTGOMERY	NEW CUMBERLAND	PIKE ISLAND	HANNIBAL	WILLOW ISLAND
GENERAL							
River Mile	6.2	13.3	31.7	54.4	84.2	126.4	161.7
District	Pittsburgh	Pittsburgh	Pittsburgh	Pittsburgh	Pittsburgh	Pittsburgh	Huntington
In-Service Date	1921	1929	1936	1959	1963	1972	1975
Upper Pool Elevation	710	692	682	664.5	644	623	602
Lower Pool Elevation	692	682	664.5	644	623	602	582
Lift (ft)	18	10	17.5	20.5	21	21	20
Top/Lock Elevation	718	704.6	692	674	656	633	616
Lock/Out Elevation	714	701	688	670.1	651.1	629	611
LOCK SIZES							
Main Lock	600' x 110'	600' x 110'	600' x 110'	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'
Auxiliary Lock	360' x 56'	360' x 56'	360' x 56'	600' x 110'	600' x 110'	600' x 110'	600' x 110'
FILLING/EMPTYING SYSTEM							
Main Lock Type	Multivalve-Direct	Side Port	Side Port	Side Port	Side Port	Side Port	Side Port
Culvert Size	N/A	11' x 14'-7"	11' x 14'-7"	15'-6" x 15'-6"	15'-6" x 15'-6"	15' x 16'	16' x 18'
Operating Valves	5'4"Butterfly (13)	Butterfly	Butterfly	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Locatn	River - Direct	Lower Approach	Lower Approach	Lower App+River	River - Direct	River - Direct	River - Direct
Depth Over Sill	17.0' U - 12.9'L	13.4'U - 18.5'L	16.0'U - 14.6'L	12.5'U - 14.8'L	17.0'U - 14.8'L	35.8'U - 14.8'L	27.4'U - 15.0'L
Aux Lock Type	Multivalve-Direct	Side Port (R Wall)	Side Port (R Wall)	Bottom Lateral	Bottom Lateral	Bottom Lateral	Bottom Lateral
Culvert Size	N/A	10' x 12'	10' x 12'	15'-6" x 15'-6"	15'-6" x 15'-6"	15' x 16'	16' x 18'
Operating Valves	5'-4" Butterfly (6)	Butterfly	Butterfly	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Locatn	River - Direct	River + Low App	River + Low App	Lower Approach	River - Direct	River - Direct	River - Direct
Depth Over Sill	15.5'U - 12.9'L	13.4'U - 18.5'L	16.0'U - 14.6'L	12.5'U - 14.8'L	17.0'U - 14.8'L	17.0'U - 14.8'L	27.4'U - 15.0'L
APPROACH WALLS							
Main Lock - Upper Wall							
Type	Guide	Guide	Guide	Guard (Ported)	Guard (Ported)	Guard (Ported)	Guard (Ported)
Length (Useable)	525'	490'	489'	1082'	1074'	1200'	1201'
- Lower Wall							
Type	Guard	Guide	Guide	Guard (Solid)	Guard (Solid)	Guard (Solid)	Guard (Solid)
Length (Useable)	577'	491'	490'	1057'	1054'	1440'	1091'
Aux Lock - Upper Wall							
Type	Guard (Ported)	Guard (Ported)	Guard (Ported)	Guide	Guide	Guide	Guide
Length (Useable)	145'	163'	110'	352'	444'	398'	364'
- Lower Wall							
Type	Guard (Solid)	Guard (Ported)	Guard (Solid)	Guard	Guard	Guard	Guard
Length (Useable)	199'	111'	161'	462'	465'	204'	398'
NAVIGABLE WEIRS							
Type	None	None	None	None	None	None	None
Length	N/A	N/A	N/A	N/A	N/A	N/A	N/A

REMARKS

NOTES: "Useable" Length of approach walls means that length of wall available to an approaching tow for landing.
"Depth over sill" means depth over highest feature in the approach, usually a bulkhead sill

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Table ED 2-1. Ohio River Project Characteristics (continued)

	BELLEVILLE	RACINE	R C BYRD (Gallipolis)	GREENUP	MELDAHL (New Richmond)	MARKLAND
GENERAL						
River Mile	203.9	237.5	279.2	341	436.2	531.5
District	Huntington	Huntington	Huntington	Huntington	Huntington	Louisville
In-Service Date	1965	1967	1993	1959	1962	1959
Upper Pool Elevation	582	560	538	515	485	455
Lower Pool Elevation	560	538	515	435	455	420
Lift (ft)	22	22	23	30	30	35
Top/Lock Elevation	596	580	560	537	505	466
Lock/Out Elevation	591	575		531	499	463
LOCK SIZES						
Main Lock	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'
Auxiliary Lock	600' x 110'	600' x 110'	600' x 110'	600' x 110'	600' x 110'	600' x 110'
FILLING/EMPTYING SYSTEM						
Main Lock Type	Split Lateral	Side Port	Side Port	Split Lateral	Split Lateral	Split Lateral
Culvert Size	15' x 16'	15'x16'(15'x18'@Ports)	16' x 18'	16' x 18'	16' x 18'	16' x 18'
Operating Valves	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Location	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct
Depth Over Sill	20.0'U - 15.0'L	18.0'U - 15.0'L	18.0'U - 18.0'L	18.0'U - 15.0'L	18.0'U - 15.0'L	25.0'U - 15.0'L
Aux Lock Type	Bottom Lateral	Bottom Lateral	Bottom Lateral	Bottom Lateral	Bottom Lateral	Bottom Lateral
Culvert Size	15' x 16'	15' x 16'	16' x 18'	16' x 18'	16' x 18'	16' x 18'
Operating Valves	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Location	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct
Depth Over Sill	20.0'U - 15.0'L	18.0'U - 15.0'L	28.0'U - 18.0'L	18.0'U - 15.0'L	18.0'U - 15.0'L	25.0'U - 15.0'L
APPROACH WALLS			(Upper Approach in Canal)			
Main Lock - Upper Wall						
Type	Guard (Ported)	Guard (Ported)	Guard	Guard (Ported)	Guard (Ported)	Guard (Ported)
Length (Useable)	1168'	1200'	1200'	1200'	1200'	1197'
- Lower Wall						
Type	Guard (Solid)	Guard (Solid)	Guard	Guard (Solid)	Guard (Solid)	Guard (Solid)
Length (Useable)	1091'	1090'	1000'	1050'	1090'	1050'
Aux Lock - Upper Wall						
Type	Guide	Guide	Guard	Guide	Guide	Guide
Length (Useable)	316'	370'	262'	382'	382'	379'
- Lower Wall						
Type	Guard	Guard	Guard	Guard	Guard	Guard
Length (Useable)	440'	371'	490'	380'	340'	380'
NAVIGABLE WEIRS						
Type	None	None	None	None	None	None
Length	N/A	N/A	N/A	N/A	N/A	N/A
REMARKS						

NOTES: "Useable" Length of approach walls means that length of wall available to an approaching tow for landing.
"Depth over sill" means depth over highest feature in the approach, usually a bulkhead sill

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Table ED 2-1. Ohio River Project Characteristics (continued)

	McALPINE	CANNELTON	NEWBURGH	J T MYERS	SMITHLAND	OLMSTED
GENERAL	(L/D 41)			(Uniontown)	(Dog Island)	(Under Construction)
River Mile	606.8	720.7	776.1	846	918.5	964.4
District	Louisville	Louisville	Louisville	Louisville	Louisville	Louisville
In-Service Date	1961-2003	1971	1975	1975	1979	2008 (Scheduled)
Upper Pool Elevation	420	383	358	342	324	295-301
Lower Pool Elevation	383	358	342	324	302	Uncontrolled
Lift (ft)	37	25	16	18	22	21 (Nominal)
Top/Lock Elevation	443	402	380	362	344	310
Lock/Out Elevation	440	399	377	359	341	295-301
LOCK SIZES						
Main Lock	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'	1200' x 110'
Auxiliary Lock	1200' x110' (2003)	600' x 110'	600' x 110'	600' x 110'	1200' x 110'	1200' x 110'
FILLING/EMPTYING SYSTEM						
Main Lock Type	Split Lateral (Existing)	Side Port	Side Port	Side Port	Side Port	Side Port
Culvert Size	16' x 18'	16' x 18'	14' x 16'	14' x 16'	14' x 18'	14' x 18'
Operating Valves	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Location	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct
Depth Over Sill	18.0'U - 12.0'L	15.0'U - 15.0'L	18.0'U - 16.0'L	20.0'U - 16.0'L	34.0'U - 15.0'L	34' to 40'U - 18'L
Aux Lock Type	Central Culverts (UC)	Bottom Lateral	Bottom Lateral	Bottom Lateral	Side Port	Side Port
Culvert Size	16' x 18'	16' x 18'	14' x 16'	14' x 16'	14' x 18'	14' x 18'
Operating Valves	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter	Reverse Tainter
Discharge Location	Lower Approach	River - Direct	River - Direct	River - Direct	River - Direct	River - Direct
Depth Over Sill	18.0'U - 16.0'L	15.0'U - 15.0'L	18.0'U - 16.0'L	20.0'U - 16.0'L	34.0'U - 15.0'L	34' to 40'U - 18'L
APPROACH WALLS	(Upper Approach in Canal)					
Main Lock - Upper Wall						
Type	Guard (Ported)	Guard (Ported)	Guard (Ported)	Guard (Ported)	Guard (Ported)	Guard (Floating)
Length (Useable)	1010'	1188'	1190'	1198'	900'	900'
- Lower Wall						
Type	Guard (Ported)	Guard (Solid)	Guard (Solid)	Guard (Solid)	Guard (Solid)	Guard (Floating w/ Curtains)
Length (Useable)	1094'	1002'	1009'	998'	1050'	852'
Aux Lock - Upper Wall						
Type	Guide	Guide	Guide	Guide	Guard (Ported)	Guard (Floating)
Length (Useable)	390'	430'	310'	310'	600'	767'
- Lower Wall						
Type	Guide	Guide	Guard	Guard	Guide	Guide (Fixed)
Length (Useable)	600'	439'	426'	448'	450'	359'
NAVIGABLE WEIRS						
Type	None	None	1300'	2100'	1572'	1400'
Length	N/A	N/A	Fixed	Fixed	Fixed	Boat Operated Wickets
REMARKS						

NOTES: "Useable" Length of approach walls means that length of wall available to an approaching tow for landing.
"Depth over sill" means depth over highest feature in the approach, usually a bulkhead sill
"Aux Lock" refers to the landward 1200' lock at the McAlpine, Smithland and Olmsted projects.

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Section 3

OHIO RIVER HYDROLOGY AND HYDRAULICS

The Ohio River flows through three districts (Pittsburgh, Huntington and Louisville) of the Great Lakes and Ohio River Division. There exists in the three district offices much hydrology information that is useful to the Ohio River Mainstem Systems Study (ORMSS). The data are collected and retained in different formats depending on the capabilities of the satellite, number of DCP's, computer systems, etc. Also the length of record, time intervals of the data, and presentation will vary from district to district. New technology, such as the Internet, world wide web and home pages have made hydrology information readily available to other Corps of Engineers districts, federal and state agencies, architect-engineers, and the general public. The information, tables and plates presented in the following paragraphs highlight types of available data. Except for a table of the lake projects in the Ohio River Basin, only samples of available data will be presented in this part of the ORMSS report. The lakes in each district will show only the drainage area and the year its operation began because they are two of the main pieces of information needed to evaluate how a historical flood profile would be affected by existing conditions. If a full period of record data is required for a project, it will be in the volume titled, "(Study Project) Lock & Dam Site Engineering Appendix.

3.1 BASIN CHARACTERISTICS

The Ohio River is unique in that the stream mileage is measured from its headwater location in Pittsburgh, where the Allegheny and the Monongahela Rivers meet to form the Ohio River downstream approximately 981 miles until it empties into the Mississippi River near Cairo, IL. The total drainage area of the Ohio River Basin is 203,943 square miles.

The Pittsburgh District, known as the Headwaters District is comprised of the Ohio River drainage basin above New Martinsville, WV. The downstream limit of the Pittsburgh District is at river mile 127.2. The District covers an area of approximately 26,000 square miles (67,000 square km), including portions of Pennsylvania, West Virginia, Ohio, New York and Maryland. Major river systems within the District include the upper Ohio, the Allegheny, the Monongahela and the Beaver Rivers. The District manages 16 flood control and multipurpose reservoirs with a combined capacity of over 3 million acre-feet (3.8 billion cubic meters) and 23 navigation locks and dams on 330 miles (530 kilometers) of navigable waterways. Six of the locks and dams are on the Ohio River.

The Huntington District lies downstream on the Ohio River from the Pittsburgh District and the reach stretches from stream mile 127.2 to 438.0. The Louisville District has the longest reach of the Ohio River from mile 438.0 at the Huntington District line to its mouth (mile 981.0) at the Mississippi River.

3.1.1 General Topography

The topography of the Ohio River Valley varies greatly from its origin in Pittsburgh, PA where the Allegheny and Monongahela Rivers meet to form the headwaters of the Ohio River to its mouth at the Mississippi River. The main stem of the Ohio River flows in a general southwesterly direction, falling 429 feet in its 981-mile course from Pittsburgh to Cairo. The flood plain is rather narrow, owing largely to the river's creation at the southern edge of Ice Age glacial action.

In the Pittsburgh District, the valley floor averages about 0.8 miles in width and the natural gradient of the streambed is about 1.0 feet per mile. Present stream banks generally average 20-25 feet in height except in the Emsworth pool where they average 10-15 feet high. Several islands are found in the Ohio River and the highly industrialized Neville Island is located in the Emsworth and Dashields pools.

The flood plain width averages more than a mile between Cincinnati and Louisville. At Louisville, the Ohio River floodplain widens to approximately four miles and then contracts to a mile below the Salt River. However, a floodwall around Jefferson County and the city of Louisville in Kentucky along with New Albany and Jeffersonville, Indiana floodwalls, limits the width to about a mile. Near the mouth, the Ohio River floodplain again widens to about six to eight miles. Elevations vary from 100 to 600 feet below the plateaus surrounding the valley. The only falls are at Louisville, where a 26-feet difference in water surface between the upper and lower pools existed prior to canalization. Numerous islands have been formed in the river over the centuries. Large bends or oxbows in the river give the stream a picturesque look. However in some areas like the Kentucky Peninsula across the stream from Evansville, Indiana, floodwaters have caused erosion problems and threaten to cut through the oxbow from the continuous flooding of the land.

3.1.2 Major Tributaries

Tributaries in the Ohio River Basin vary from very steep mountain streams with cascades and rapids to sluggish, meandering, marsh-like areas. Slopes of major tributaries vary from more than 100 feet per mile in the headwaters to less than two-tenths of a foot per mile in the flat areas near the main stem. In general, the streams are considerably steeper in the headwaters, becoming relatively flat near the mouth. Post-glacial changes in stream patterns, local layers of hard rock and distribution of tributaries may cause local modifications in profiles.

Table ED 3-1entitled "Ohio River & Tributaries Drainage Areas", has been developed which shows the river mile and total drainage area at major communities, former dam locations, and at the present locks and dams. Also provided are the river miles of major tributaries, which shows the contributing drainage area to the Ohio River at that point. As shown in Table 3.1.2-1, the Pittsburgh District has information on the lengths and average slopes of the main tributaries.

Table ED 3-1. Ohio River & Tributaries Drainage Areas

RIVER MILE	SITE	BANK	DRAINAGE AREA (SQ. MI.)	LENGTH (MILES)	AVERAGE SLOPE (FEET/MILE)	OHIO RIVER DRAINAGE AREA (SQ. MI.)
	Allegheny River					**11,748**
	Monongahela River					**7,384**
	Head of the Ohio River					**19,132**
0.7	Saw Mill Run	Left	19.4	9.6	47.0	
2.6	Chartiers Creek	Left	277.0	52.0	11.0	
6.2	**Emsworth Locks & Dam**					**19,428**
6.2	Lowries Run	Right	17.0	8.3	55.0	
9.4	Montour Run	Left	36.6	11.5	43.0	
11.8	**Sewickley, PA**					**19,500**
13.3	**Dashields Locks & Dam**					**19,522**
15.4	Big Sewickley Creek	Right	30.2	10.5	40.0	
22.2	Crows Run	Right	13.8	7.4	55.0	
25.4	Beaver River	Right	3153.0	87.5	3.4	
29.6	Raccoon Creek	Left	184.0	45.0	12.0	
31.7	**Montgomery Locks & Dam**					**22,969**
39.5	Little Beaver Creek	Right	503.0	15.9	12.1	
40.1	Mill Creek	Left	15.5	6.3	73.0	
47.1	Little Yellow Creek	Right	22.7	10.4	43.6	
50.4	Yellow Creek	Right	239.0	32.1	10.1	
54.4	**New Cumberland Locks & Dam**					**23,870**
60.1	Kings Creek	Left	49.6	14.2	36.3	
61.7	Island Creek	Right	26.4	9.3	57.3	
66.7	Harmon Creek	Left	39.0	16.3	37.3	
71.6	Indian Cross Creek	Right	128.0	30.5	19.8	
71.6	Virginia Cross Creek	Left	79.9	23.2	26.0	
74.7	Buffalo Creek	Left	163.0	39.8	13.5	
81.4	Indian Short Creek	Right	148.0	24.4	23.4	
81.5	Virginia Short Creek	Left	24.4	10.1	56.4	
84.2	**Pike Island Locks & Dam**					**24,639**
90.2	Wheeling Creek, OH	Right	108.0	31.0	18.0	
85-93	**Wheeling, WV**					**24,800**
90.7	Wheeling Creek, WV	Right	298.0	29.35	7.9	
94.7	McMahon Creek	Right	91.0	27.9	20.4	
102.4	Grave Creek	Left	74.8	22.2	29.1	
109.6	Captina Creek	Right	180.0	25.9	10.2	
113.8	Fish Creek	Left	229.0	26.85	7.1	
118.0	Sunfish Creek	Right	114.0	31.4	16.3	
119.8	Opossum Creek	Right	25.4	13.0	47.3	
122.3	Proctor Creek	Left	22.0	8.9	53.7	
126.4	**Hannibal Pool Locks & Dam**					**25,960**
127.2	**Pittsburgh-Huntington District Line**					**25,966**

Table ED 3-1. Ohio River & Tributaries Drainage Areas

RIVER MILE	SITE	BANK	DRAINAGE AREA (SQ. MI.)	LENGTH (MILES)	AVERAGE SLOPE (FEET/MILE)	OHIO RIVER DRAINAGE AREA (SQ. MI.)
155.0	**St. Marys, WV**					**26,850**
161.7	**Willow Island Locks and Dam**					**26,900**
172.2	Muskingum River	Right	8040			
184.4	**Parkersburg, WV**					**35,600**
184.6	Little Kanawha River	Left	2320			
199.3	Hocking River	Right	1190			
203.9	**Belleville Locks and Dam**					**39,302**
237.5	**Racine Locks and Dam**					**40,130**
265.3	**Pomeroy, OH**					**40,500**
265.7	Kanawha River	Left	12,200			
265.8	**Point Pleasant**					**52,760**
279.2	**R.C. Byrd (Gallipolis) Locks and Dam**					**53,300**
305.2	Guyandotte River	Left	1670			
311.6	**Huntington, WV**					**55,900**
317.1	Big Sandy River	Left	4294			
322.5	**Ashland, KY**					**60,750**
341.0	**Greenup Locks and Dam**					**62,000**
356.5	Scioto River	Right	6510			
408.6	**Maysville, KY**					**70,130**
436.2	**Meldahl Locks and Dam**					**70,808**
438.0	**Huntington-Louisville District Line**					**70,820**
464.1	Little Miami River	Right	1760			
470.2	Licking River	Left	3707			
470.5	**Cincinnati, OH**					**76,580**
491.1	Great Miami River	Right	5400			
531.5	**Markland Locks and Dam**					**83,170**
545.7	**above Kentucky River**					**83,320**
545.8	Kentucky River	Left	6966			
557.7						**90,580**
607.3	**McAlpine Locks and Dam**					**91,170**
627.1	**Kosmosdale**					**91,440**
629.9	Salt River	Left	2920			
633.2	**Dam 43**					**94,440**
663.2	**Dam 44**					**95,685**
703.0	**Dam 45**					**96,260**
720.7	**Cannelton Locks and Dam**					**97,000**
727.8	**Tell City**					**96,750**
757.3	**Dam 46**					**97,180**
755-757	**Owensboro, KY**					**97,200**

Table ED 3-1. Ohio River & Tributaries Drainage Areas

RIVER MILE	SITE	BANK	DRAINAGE AREA (SQ. MI.)	LENGTH (MILES)	AVERAGE SLOPE (FEET/MILE)	OHIO RIVER DRAINAGE AREA (SQ. MI.)
776.1	**Newburgh Locks and Dam**					**97,690**
777.7	**Dam 47**					**97,690**
784.2	Green River	Left	9230			
792.4	**Evansville**					**107,000**
803.9	**Henderson, KY**					**107,600**
809.6	**Dam 48**					**107,600**
829.2	**Mt. Vernon, IN**					**107,700**
845.0	**Dam 49**					**107,965**
846.0	**J.T. Myers Locks and Dam** (Uniontown)					**108,000**
848.0	Wabash River	Right	33,100			
867.3	Saline River	Right	1170			
873.4	Tradewater River	Left	1000			
876.8	**Dam 50**					**143,400**
903.1	**Dam 51** (Golconda, IL)					**143,900**
918.5	**Smithland Locks and Dam**					**144,000**
920.4	Cumberland River	Left	17,920			
934.5	Tennessee River	Left	40,910			
934.8	**Paducah**					**202,800**
938.9	**Dam 52**					**202,830**
943.6	**Metropolis, IL**					**203,000**
962.6	**Dam 53** (near Grand Chain, IL)					**203,100**
964.4	**Olmsted Locks and Dam** (Under Const.)					**203,100**
974.2	**Mound City, IL**					
981.0	**Mouth of the Ohio River**					**203,943**

3.2 HYDROLOGY

3.2.1 Upstream Reservoir and Flood Protection Projects

The January 1937 basin-wide flood and the increase in industry tow traffic made a major impact on the water facilities in the three districts. Although a few flood control and multipurpose lakes were completed or were under construction in 1937, many more dams and lakes were built after this flood so that at present there are 72 lake projects. This does not include projects in the Nashville District, which affect the Ohio River below the Cumberland and Tennessee Rivers. These rivers enter in the lower reach of the Ohio River where two 1200' locks already exist at Smithland Locks & Dam and where construction is underway on two 1200' locks at Olmsted Lock & Dam (total project

completion date is 2008). A list of reservoirs with their drainage areas and approximate date of completion are shown on Table ED 3-2.

There are no Corps of Engineers local flood protection projects consisting of floodwalls, levees or dikes along the main stem Ohio River in the Pittsburgh District. However, there are numerous local protection projects in the Huntington and Louisville Districts. These local protection projects will not be affected by expanded and added lock projects since pool levels would not be changed.

3.2.2 Stream Gauging Stations and Records

The records of flooding in the Pittsburgh area were obtained at Fort Duquesne at the junction of the Allegheny and Monongahela Rivers as early as 1765. Later, when navigation became a more dominant factor in colonial activity, gages were established on the Monongahela River wharf and records are found from this source.

The collection of systematic hydrologic records on the Ohio River dates back to the flood heights recorded at Pittsburgh in 1806. At first, only significant hydrologic events were recorded. These events usually consisted of floods of unusual magnitude, extent or duration. It was not until 1855, when the U.S. Army Signal Corps made regular daily observations, later replaced by the U.S. Weather Bureau in 1878, that continuous records became available. However, continuous record collection on the Ohio River began at Pittsburgh in 1847, Cincinnati in 1858, and Louisville in 1866. Each district maintains a database of hydrologic information for their respected reach. Continuous hydrologic records are kept at locks and dams on the Ohio River. In addition, many communities and flood control projects have gages that provide a continuous record. Records of stage are most readily available with stream flow records being less common.

Corps of Engineers (COE) Pittsburgh District staff gages are located on the upper and lower lock walls at Emsworth, Dashields, Montgomery, New Cumberland, Pike Island and Hannibal Locks and Dams. Auxiliary staff gages are installed above the lock walls to measure high water events. Staff gage measurements are taken by lock personnel and have been recorded since the time of construction in three-hour increments and hourly during high water events. Each dam has a critical river height at which these hourly readings are recorded and this procedure continues until the river recedes.

Digital automatic stage records are available for the Ohio River at Pittsburgh's "Point" gage, the upper and lower pools at Emsworth Locks and Dam, New Cumberland Locks and Dam, Pike Island Locks and Dam and Hannibal Locks and Dam. The measurement equipment includes chart recorders and remote transmitters. The digital readouts are located within the projects for the purpose of continuous monitoring.

Data Collection Platform (DCP) gages are located on the Ohio River at Emsworth Locks and Dam, East Liverpool, New Cumberland Locks and Dam, Pike Island Locks and Dam, Wheeling, Dilles Bottom, and Hannibal Locks and Dam. The stage readings are automatically recorded and transmitted to the Pittsburgh District's data storage system using satellite telemetry. They have been in operation since the early 1980's.

River stage readings have been recorded at the USGS gauging station, Ohio River at Sewickley, Pennsylvania since October 1933. Currently, an automatic continuous recording DCP gage with satellite telemetry is located on the upstream side of Dashields Locks and Dam. This station has a fixed-crest dam control, which merits it with a good stage-discharge relationship.

TABLE ED 3-2 LAKE PROJECTS IN THE OHIO RIVER BASIN

RIVER BASIN	LAKE PROJECT	DRAINAGE AREA	IN OPERATION DATE PLACED
	PITTSBURGH DISTRICT		
Allegheny River, Pennsylvania	Kinzua Dam and Allegheny Reservoir	2,180 sq. mi.	1967
	Tionesta Lake	478 sq. mi.	1940
	Union City Dam	222 sq. mi.	1971
	Woodcock Creek Lake	45.7 sq. mi.	1974
	East Branch Clarion River Lake	72.4 sq. mi.	1952
	Mahoning Creek Lake	340 sq. mi.	1941
	Crooked Creek Lake	277 sq. mi.	1940
	Conemaugh River Lake	1,351 sq. mi.	1952
	Loyalhanna Lake	290 sq. mi.	1942
Monongahela River, West Virginia	Stonewall Jackson Lake	102 sq. mi.	
	Tygart Lake	1,184 sq. mi.	1938
Monongahela River, Maryland	Youghiogheny River	434 sq. mi.	1948
Beaver River, Ohio	M. J. Kirwan Dam and Reservoir	80.5 sq. mi.	1967
	Berlin Lake	249 sq. mi.	1943
	Mosquito Creek Lake	97.4 sq. mi.	1944
Beaver River, Pennsylvania	Shenanro River Lake	589 sq. mi.	1967
	HUNTINGTON DISTRICT		
Muskingum River, Ohio	Atwood Lake	70 sq. mi.	1937
	Beach City Lake	300 sq. mi.	1937
	Bolivar Lake	502 sq. mi.	1938
	Charles Mill Lake	215 sq. mi.	1936
	Clendening Lake	69 sq. mi.	1937
	Dillon Lake	742 sq. mi.	1961
	Dover	1,397 sq. mi.	1938
	Leesville Lake	48 sq. mi.	1937
	Mohawk Lake	1,504 sq. mi.	1937
	Mohicanville Lake	271 sq. mi.	1937
	North Branch of Kokosing Lake	44.5 sq. mi.	1971

TABLE ED 3-2. LAKE PROJECTS IN THE OHIO RIVER BASIN (continued)

RIVER BASIN	LAKE PROJECT	DRAINAGE AREA	IN OPERATION DATE PLACED
Miami River, Ohio	Clarence J. Brown Dam and Reservoir	82 sq. mi.	January 1974
Whitewater River, Indiana	Brookville Lake	379 sq. mi.	January 1974
Kentucky River, Kentucky	Carr Creek Lake	58 sq. mi.	January 1976
	Buckhorn Lake	408 sq. mi.	December1961
Salt River, Kentucky	Taylorsville Lake	353 sq. mi.	January 1983
Green River, Kentucky	Green River Lake	682 sq. mi.	June 1969
	Nolin River Lake	703 sq. mi.	March 1963
	Barren River Lake	940 sq. mi.	October 1964
	Rough River Lake	454 sq. mi.	September 1959
Wabash River, Indiana	J. Edward Roush Lake	707 sq. mi.	October 1968
	Salamonie Lake	553 sq. mi.	September 1966
	Mississinewa Lake	809 sq. mi.	October 1967
	Cecil M. Harden Lake	216 sq. mi.	July 1960
	Cagles Mill Lake	295 sq. mi.	June 19553
	Monroe Lake	441 sq. mi.	February 1965
	Patoka Lake	168 sq. mi.	August 1980
	NASHVILLE DISTRICT		
Cumberland River, Kentucky	Martin's Fork Lake	55.7 sq. mi.	1978
	Laurel River Lake	282 sq. mi.	1977
	Lake Cumberland	5,789 sq. mi.	1950
Cumberland River, Tennessee	Dale Hollow Lake	935 sq. mi.	1943
	Cordell Hull Lake	8,096 sq. mi.	1973
	Center Hill Lake	2,174 sq. mi.	1948
	Old Hickory Lake	11,674 sq. mi.	1957
	J.Percy Priest Lake	892 sq. mi.	1967
	Cheatham Lake	14,160 sq. mi.	1959
Cumberland River, Kentucky	Lake Barkley	17,598 sq. mi.	1966

Table ED 3-3. Pittsburgh District Historical Minimum and Maximum Flow Rates at Various Gauging Stations (Flow in cfs)

Station	Drainage Area	Period of Record	Minimum Flow	Minimum Date	Maximum Flow	Maximum Date
Ohio River						
Sewickley, PA	19,522	1933-date	1800	9/57	574,000	3/36
New Cumberland L/D	23,873	1959-date	----	----	386,000	6/72
Wheeling, WV	24,666	1838-date	----	----	373,000	6/72

Over the years flow measurements have been made to develop rating curves at gage locations to show the relationship between stage and flow. The stage data that is obtained provides instantaneous information and together with highwater marks form the basis of the historical flood profiles.

The locations of various stream flow gages in the Huntington and Louisville Districts, together with other pertinent data, are contained in Table ED 3-4 and ED 3-5, respectively. Although not discussed in detail as for the Pittsburgh District above, the Huntington and Louisville Districts have staff gages, digital automatic stage recorders, DCP gages with satellite telemetry to provide instantaneous and continuous recording of data.

Data is available from the files of Table ED 3-5 in the Louisville District so that annual peaks and all peaks above a specified elevation can be provided both chronologically and in order of magnitude for the period of record. An example for the J. T. Myers upper gage is provided in Table ED 3-6.

Table ED 3-4. Huntington District Ohio River Stream Flow Gaging Stations

Station Locations	River Mile	Drainage Area (square miles)	Period of Record	Maximum Stage (ft)	Gage Datum (ft)	
Saint Marys, WV	155.0	26,850	1913-1972	54.20	577.30	(1)
Marietta, OH	174.3	35,600	1968-Present	38.52	567.12	(1)
Pomeroy, OH	251.3	40,520	1913-1968	55.00	514.10	(1)
Point Pleasant, WV	265.2	52,760	1940-Present	55.00	514.00	(1)
Huntington, WV	308.3	55,900	1935-Present	61.60	490.26	(1)
Ashland, KY	322.5	60,750	1884-Present	73.60	483.10	(1)
Greenup L&D	341.0	62,000	1968-Present	50.96	472.97	(2)
Maysville, KY	408.6	70,130	1937-Present	75.30	451.50	(1)

(1.) Denotes Sandy Hook Datum.
(2.)Denotes 1929 Datum.

Table ED 3-5. Louisville District Ohio River Stations

CODE	STATION	RIVER-MILE**	ORD DATUM	PERIOD
001	EVANSVILLE	792.3	329.2	1930-1999
100	MT VERNON	829.2	318.9	1930-1991
300	TELL CITY (COMPOSITE)	727.7	347.6	1930-1991
390	MARKLAND (CLG)	531.9	408.0	1930-1999
391	MARKLAND (UPR)	531.2	443.0	1963-1999
392	MARKLAND (LWR)	531.9	408.0	1963-1999
393	LOCK 39 (LWG)	531.7	411.0	1930-1936
401	J.T.MYERS (UPR)	845.8	330.0	1970-1999
402	J.T.MYERS (LWR)	846.2	312.0	1970-1999
410	MCALPINE (CLG)	606.8	374.0	1976-1982
411	MCALPINE (UPR)	607.3	408.0**	1875-1999
412	MCALPINE (LWR)	606.8	374.0	1875-1999
415	MCALPINE (WWG)	606.8		1961-1970
420	KOSMOSDALE	627.1	374.0	1972-1999
510	GOLCONDA + LD51 (CLG)	903.2	293.0	1930-1980
511	GOLCONDA + LD51 (UPR)	902.9	294.6	1930-1989
515	PADUCAH	934.6	286.3	1965-1999
520	BROOKPORT LK52 (CLG)	938.7	281.0	1930-1995
521	BROOKPORT LK52 (UPR)	939.1	283.3	1930-1999
522	BROOKPORT LK52 (LWR)	938.7	281.0	1930-1999
530	LOCK 53 (CLG)	962.4	273.1	1930-1995
531	LOCK 53 (UPR)	962.8	273.1	1930-1999
532	LOCK 53 (LWR)	962.4	273.1	1930-1999
534	GRAND CHAIN RECORDING	962.1	276.6	1930-1969
555	SMITHLAND(UPR)	918.8	312.0	1981-1999
556	SMITHLAND(LWR)	918.3	290.0	1981-1999
601	CANNELTON(UPR)	720.5	374.0	1971-1999
602	CANNELTON(LWR)	720.9	348.0	1968-1999
701	NEWBURGH(UPR)	775.9	348.0	1971-1999
702	NEWBURGH(LWR)	776.3	330.0	1971-1999
800	CAIRO	979.5	270.9	1930-1999
802	MELDAHL(LWR)	436.7	443.0	1965-1999
900	CINCINNATI	470.5	429.6	1930-1999
901	CINCINNATI(ADJ)	470.5	429.6	1950-1990

* RIVER MILEAGE ADJUSTED FROM HIGHWATER PROFILES
** STAGE VALUES BEFORE JAN 1965 HAVE BEEN ADJUSTED FOR NEW DATUM

Table ED 3-5

OHIO RIVER AT J.T.MYERS(UPR)
RIVER ELEVATION FREQUENCY TABLE
(FOR PERIOD SEP 1975 - OCT 1998)

ANNUAL PEAKS (BY WATER YEAR)

YEAR	PEAK	DATE
1976	355.30	27 FEB 1976
1977	351.60	13 APR 1977
1978	358.70	23 MAR 1978
1979	362.50	08 MAR 1979
1980	352.50	29 MAR 1980
1981	350.80	14 JUN 1981
1982	355.40	26 MAR 1982
1983	360.90	10 MAY 1983
1984	354.20	15 MAY 1984
1985	354.70	05 MAR 1985
1986	356.00	07 DEC 1985
1987	349.70	18 APR 1987
1988	350.90	10 FEB 1988
1989	357.40	24 FEB 1989
1990	356.90	20 FEB 1990
1991	364.00	09 JAN 1991
1992	346.80	09 DEC 1991
1993	353.60	13 MAR 1993
1994	357.20	23 APR 1994
1995	358.80	26 MAY 1995
1996	360.00	15 MAY 1996
1997	366.00	11 MAR 1997
1998	353.90	27 APR 1998

PEAKS IN PERIOD (BY ORDER OF OCCURANCE)

PEAK	DATE
351.10	9 JAN 1976
355.30	27 FEB 1976
351.60	13 APR 1977
351.00	3 FEB 1978
358.70	23 MAR 1978
359.00	18 DEC 1978
352.40	9 JAN 1979
352.50	29 JAN 1979
362.50	8 MAR 1979
354.20	18 APR 1979
352.50	29 MAR 1980
350.80	14 JUN 1981
351.20	29 JAN 1982
351.00	9 FEB 1982
355.40	26 MAR 1982
360.90	11 MAY 1983
353.40	23 MAY 1983
353.50	5 APR 1984
354.10	30 APR 1984
354.20	15 MAY 1984
354.70	5 MAR 1985
351.90	7 APR 1985
356.00	7 DEC 1985
353.00	14 FEB 1986
350.90	10 FEB 1988
357.40	24 FEB 1989
352.20	14 MAR 1989
355.50	9 APR 1989
356.90	21 FEB 1990
351.90	23 MAY 1990
351.00	3 JUN 1990
364.00	9 JAN 1991
354.30	31 MAR 1991
353.60	13 MAR 1993
352.40	4 APR 1993
356.70	6 FEB 1994
352.20	3 MAR 1994
354.10	18 MAR 1994
357.20	23 APR 1994
358.80	26 MAY 1995
357.20	31 JAN 1996
360.00	16 MAY 1996
366.00	13 MAR 1997
353.90	27 APR 1998
352.10	12 MAY 1998

PEAKS IN PERIOD (BY ORDER OF MAGNITUDE)

PEAK	DATE
366.00	13 MAR 1997
364.00	09 JAN 1991
362.50	08 MAR 1979
360.90	11 MAY 1983
360.00	16 MAY 1996
359.00	18 DEC 1978
358.80	26 MAY 1995
358.70	23 MAR 1978
357.40	24 FEB 1989
357.20	23 APR 1994
357.20	31 JAN 1996
356.90	21 FEB 1990
356.70	06 FEB 1994
356.00	07 DEC 1985
355.50	09 APR 1989
355.40	26 MAR 1982
355.30	27 FEB 1976
354.70	05 MAR 1985
354.30	31 MAR 1991
354.20	18 APR 1979
354.20	15 MAY 1984
354.10	30 APR 1984
354.10	18 MAR 1994
353.90	27 APR 1998
353.60	13 MAR 1993
353.50	05 APR 1984
353.40	23 MAY 1983
353.00	14 FEB 1986
352.50	29 JAN 1979
352.50	29 MAR 1980
352.40	09 JAN 1979
352.40	04 APR 1993
352.20	14 MAR 1989
352.20	03 MAR 1994
352.10	12 MAY 1998
351.90	07 APR 1985
351.90	23 MAY 1990
351.60	13 APR 1977
351.20	29 JAN 1982
351.10	09 JAN 1976
351.00	03 FEB 1978
351.00	09 FEB 1982
351.00	03 JUN 1990
350.90	10 FEB 1988
350.80	14 JUN 1981

3.2.3 Historical and Recorded Floods

Storm patterns and the length of the Ohio River can produce record floods occurring in one district with little or no flooding in the other districts. The exception is the January 1937 flood, which was the modern day major flood in the basin.

In the Pittsburgh District, the highest known floods prior to the construction of flood control projects occurred March 15, 1907 with a peak of 732.7 feet above National Geodetic Vertical Datum (NGVD), January 9, 1763 with a peak of 735.1 (NGVD) and March 18, 1936 with a peak of 740.2 feet above NGVD at the Pittsburgh "Point". Since the 1936 flood, twelve flood control reservoirs have been built in the Allegheny and Monongahela River basins which provide flood protection on the Ohio River from Pittsburgh on downstream. In addition, four reservoirs in the Beaver River basin (built 1943-1967) effect reductions in flood stages in the Montgomery pool and downstream.

The March 1936 (St. Patrick's Day) Flood occurred prior to the construction of any Corps of Engineers' flood control dams. The base flow for the Ohio River on March 9 was 50,100 cfs. Water content of the snow in the district was 2" to more than 4" in the mountains. Melting snow and about 0.65 inches of precipitation caused a rise on the 12th-13th at which time the "Point" gage reached 25.8 feet and was above flood stage for 21 hours. Essentially all snow was melted at this time. Although the flow receded to 99,300 cfs on the 16th, anywhere from 2.5" to 5" of rain fell on the 16th and 17th, with the heaviest in the Lower Allegheny basin. This sent the Ohio River at Pittsburgh to a crest of 46 feet (740.2 feet above NGVD and 557,000 cfs), the river remained above flood stage for 84 hours. It would have been reduced by 10.7 feet with the present reservoir system. A third rise occurred on the 25th-26th during which the river was above flood stage for 32 hours, cresting at 30.6 feet. Total runoff for the month of March 1936 was 8.74 inches at Pittsburgh.

The June 23, 1972 Flood, a result of Tropical Storm Agnes, produced the highest stage at the Pittsburgh "Point" using the current reservoir system. The Ohio River flow on June 20th was 23,700 cfs at the "Point". From the 20th through the 26th, the Allegheny Basin received from 4" to 12" of rainfall and the Monongahela Basin from less than 3" to over 12". The Ohio River crested at Pittsburgh at 35.85 feet (730.0 feet above NGVD and 380,000 cfs), remaining above flood stage for 86 hours. It would have been 12.1 feet higher without the current reservoir system. The runoff during the flood at Pittsburgh was 4.65 inches for the period June 21-July 15, 1972.

Table ED 3-6 presents peak water surface elevations for historic high water events, including the March 1936 and June 1972 floods at the Pittsburgh "Point" and Wheeling, WV.

Table ED 3-6. Historical Peak Elevation Events on the Ohio River in the Pittsburgh District

	Pittsburgh (Point), Pennsylvania	Wheeling, West Virginia
	Elevations in feet above NGVD	
March 18, 1936	740.2	666.0
December 31, 1942	730.8	662.3
June 24, 1972	730.0	657.4
April 27, 1937	729.3	656.7
January 20, 1996	728.8	654.2

Historical profiles and the way they are presented may vary from district to district. Various other information such as communities, major roads, major tributaries, etc are also shown. The historical flood profile elevations would be reduced, but to a varying degree by the new reservoirs constructed after the occurrence of the flood. All three districts have plots of historical and frequency profiles in their office files.

In the Louisville District, the April 1976 discharges for the Ohio River were the basis of the frequency profiles that were developed for the Ohio River. The factors used to develop the HEC-2 model were verified by the reproduction of historical flood profiles utilizing the April 1976 ORD stage and discharge frequency curves.

3.2.4 Natural and Existing Flood Flows

Stage data that is obtained at the recording locations do not provide a homogeneous set of data. The operation of the flood control dams upstream results in a set of data that is existing at that particular time. To obtain a natural condition, water stored for a selected time interval in each reservoir must be routed downstream and added to the appropriate gage. This would have the effect of raising the gage heights and making flood profiles higher. To obtain the present condition at a particular gage, the opposite process is required. All reservoirs that were not built or operated differently must have flows adjusted at the dam by its normal operation. The water that would have been stored for a selected time period is routed downstream and subtracted from the appropriate gage. This has the effect of lowering stages and lowering the flood profile.

Flood flows are difficult to determine for a stream the length of the Ohio River. If another reservoir project is built or an operation is changed, the modified condition will change (probably minimally). The Lakes and River Division, known as the Ohio River Division at the time of the study, using the methodology described above for all of the reservoirs in the Ohio River Basin developed discharge frequency flow curves for a number of locations. The data was labeled "19__ modified conditions. However, the division used only the annual peak at each gage in developing frequency flow data. This has little effect on floods occurring less than once in ten years. However, these curves did not include partial, multiple yearly peaks in the statistical analysis.

3.2.5 Ordinary High Water

Ordinary High Water (OHW) is a line on the bank of a river or other body of water that marks the boundary of those lands subject to navigational servitude. The public has the right to navigate freely over lands subject to navigational servitude. Also, physical facilities intended to support navigation may be placed and maintained on such lands.

The line of ordinary high water, as applied to rivers, that separates what properly belongs to the riverbed from that which belongs to the owner of adjacent land is determined by normal conditions, not by reference to unusual floods. Ordinary high water is the point on the bank where the waters are so continuous as to leave a distinct mark either by erosion, destruction or terrestrial vegetation, or other easily recognized characteristics. The most common method of identifying OHW marks is to find that elevation on the bank below which terrestrial (dry land) vegetation does not exist. Other indicators are: (1) absence of commercial agriculture, (2) drift or debris lines, (3) changes in soil characteristics, (4) benching and shelving of the bank, (5) absence of all vegetation, and (6) absence of commercial human activity.

The ordinary highwater elevation not only has an effect on the adjacent environment but also is critical on the Ohio River with relation to water supply inlets, storm and sanitary sewer outlets, permanent and floating docks, and adjacent industrial, residential and recreational facilities. The extension of present locks or the addition of a third lock would not have an effect on the ordinary highwater profile. Therefore this is of little concern in the Huntington and Louisville Districts in this study. Ordinary highwater profiles for the Ohio River are available in both districts.

There is a possibility that a study of replacing the upper three locks and dams near Pittsburgh with two locks and dams would need evaluation. This would change the ordinary highwater profile in these reaches. The Pittsburgh District is currently reevaluating Ordinary High Water for their District's six navigational pools. The 0.7 year frequency profile is estimated to be the District's Ordinary High Water for the Ohio River. Ongoing field investigations will better define the District's current Ordinary High Water line. This updated profile together with the standard project flood, the 100-year flood, the streambed, and the normal pool level resulting from the Ohio River dams, are available from the Pittsburgh district.

3.2.6 Low Flow Conditions

Low flow conditions will normally be an asset during lock expansion construction. The months when low flows can be expected are available through the gage's history or from continuous gage records. As an example, in the Pittsburgh District, the most sustained and severe period of low flow in the Ohio River occurred during the summer and autumn of 1930. The actual average flow at Pittsburgh in October 1930 dropped to 1,206 cfs. It is estimated that the October flow would have been even lower, about 900 cfs, if Lake Lynn on the Cheat River had not released water reserved for power generation. Low flow augmentation by existing reservoirs would have greatly improved these conditions. Table ED 3-7 shows the mean monthly actual, natural and augmented 1930 drought flows on the Ohio River at Pittsburgh, Pennsylvania. Also included in the table are the mean monthly flows from the more

recent droughts of 1988 and 1991 obtained from the U.S. Geological Survey Water Resources Data publication for the Ohio River at Sewickley, Pennsylvania.

Table ED 3-7. Monthly Mean Flows of the Ohio River at Pittsburgh, Pennsylvania
(Flow in cfs)

	Jul	Aug	Sep	Oct	Nov	Dec
1930 Drought						
Actual	3,979	1,284	1,273	1,206	1,563	6,643
Natural *	3,951	1,241	1,000	903	1,394	6,737
Augmented - Existing	5,708	4,205	4,186	4,156	3,740	6,712
1988 Drought	6,308	5,076	9,241	18,470	19,830	51,490
1991 Drought	6,263	4,953	5,132	49,600	31,670	74,740

* Without Lake Lynn Drawdown

The seven days, ten year frequency flow (Q7-10) is defined as a mean low flow for seven consecutive days that will recur, on the average, once in ten years. The Q7-10 flows were developed for the Ohio River based on 31 years of record for the period 1949 to 1979. Table ED 3-8 shows the Ohio River at selected points in the Pittsburgh District of the Q7-10 flows which were based on regulated conditions by the upstream reservoirs.

Table ED 3-8. Seven Day – Ten Year Flow (Q7 – 10)

Ohio River Location	Flow in cfs
Dashields Locks and Dam	4,800
Montgomery Locks and Dam	5,700
New Cumberland Locks and Dam	5,750
Pike Island Locks and Dam	5,830
Hannibal Locks and Dam	5,850

3.3 LOCK HYDRAULICS (TYPICAL FOR OHIO RIVER)

3.3.1 Approach Conditions

Before a vessel can successfully enter the lock chamber, it must first approach the lock over open water. The approach conditions are typically evaluated with physical hydraulic models to be sure that adverse currents do not occur. In some cases, it may be necessary to construct underwater dikes to modify the currents to provide for safe

approach conditions. Approach conditions can also be made difficult by wind conditions, particularly for tows with empty barges as they sit higher in the water. Final approach to the lock chamber is aided by the presence of lock approach walls both upstream and downstream of the locks. Vessels arriving at the lock will use the approach wall to align themselves properly for entry into the lock. In terms of safety and processing time, the approach characteristics of a lock are one of the most important features of the navigation projects on the Ohio River.

Approach Walls

Vessels entering or exiting a lock at low speed lack maneuverability and steerageway and are susceptible to adverse currents. Approach walls are used to safely guide vessels and tows into or out of the lock chamber. They also provide a mooring location for long tows that require multiple lockages. An additional benefit provided by some of the walls is protection from hazardous areas and adverse currents.

Typical Arrangement

For navigation projects on the Ohio River, the two typical types of approach walls are the guide and guard walls. The distinguishing feature between the two types is their position with respect to the dam. Guard walls are located between the locks and the discharging portion of the dam. The wall situated on the landward side of the lock approach is defined as the guide wall. Approach walls are further subdivided based on their location either upstream (upper) of downstream (lower) of the dam axis. Of the twenty active locks and dam on the Ohio River, thirteen have approach wall configurations as provided in Figure ED 3-1.

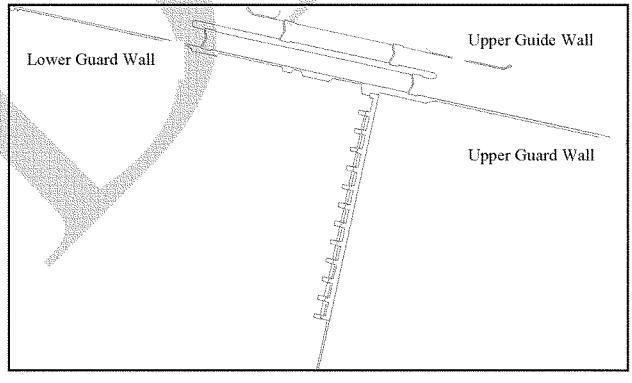

Figure ED 3-1. Typical Approach Wall Configurations

Upper Guard Wall

Downbound tows aligning for entry into the lock chamber utilize this wall. The ports typically found in this wall allow currents in the upstream approach to pass under the wall and flow towards the dam. These currents tend to hold tows against the wall, thus facilitating safe entry into the lock. Without the ports, lateral currents across the upper approach would tend to push tows towards the bullnose. The wall is configured so that the largest tows can safely align themselves for entry into the lock chamber.

Upper Guide Wall

This wall is typically used as an alignment wall for the auxiliary lock chamber. Because most of the auxiliary locks are only 600 feet long, the length of these walls is typically less than the upper guard wall. In general, vessels and tows using this wall are not adversely affected by river currents. Tows that are longer than the wall, however, may have difficulty with alignment due to the currents in the upper approach.

Lower Guard Wall

Upbound tows align for entry into the main lock chamber using this wall. It also protects against adverse currents caused by discharges from the dam. Since currents introduced through this wall would tend to push tows away from the wall, they are not ported. Downstream of the lock approach, the wall induces a slackwater "shadow" that facilitates a safer entry into the lock.

Lower Guide Wall

The typical lock configuration on the Ohio River provides a relatively short landward wall downstream of the auxiliary lock. This wall can be used to align for entry into the auxiliary lock. The middle wall serves as a landing area for upbound vessels.

Unique Approach Conditions

Several of the locks and dams on the Ohio River have approach conditions that warrant a separate discussion.

Smithland and Olmsted

A safe approach wall configuration for twin 1200 feet by 110 feet locks was developed using the physical hydraulic model tests of Smithland. The system consists of a relatively long ported guard wall and a ported middle wall. The middle wall serves as a landing surface and an alignment mechanism for downbound tows. The lower approach walls consist of a non-ported guard wall and a relatively short guide wall. This configuration allows for safe and efficient use of both lock chambers. The approach walls at Olmsted will have the same arrangement.

Emsworth, Dashields, and Montgomery

Since the main lock at each of these projects is only 600 feet long, a standard size Ohio River tow requires multiple lockages. With auxiliary locks measuring 360 feet by 56 feet, significant delays are experienced when the main lock is closed for maintenance purposes.

McAlpine

There are several unique conditions associated with the McAlpine approaches that are not experienced elsewhere in the navigation system. The approach to the canal is very close the downtown Louisville, KY area and leave little room for error. A relatively new vane dike has improved these entry conditions. In addition to the entry conditions, the presence of a railroad bridge with minimal vertical and horizontal clearances make this approach one of the most challenging in the system. In the lower approach, the guard wall is ported to alleviate adverse currents around the bullnose. Occasionally this presents a problem to upbound tows that may be pushed away from the wall. The most serious concern in the lower approach is related to the proposed discharge facilities for the new 1200 foot lock. The lock will discharge directly into the lower approach. As a result, traffic in the lower approach will be severely restricted during periods of discharge.

The action of filling the locks with water from the canal tends to induce long period surges. The period of the surges is typically thirty minutes with a magnitude of one foot. The surges and currents that they generate are such that they can interfere with the operation of the main lock. Filling operations must be performed with great caution to minimize the impact of these surges.

R.C. Byrd

The project consists of a 1200 foot main lock and a 600 foot auxiliary lock. Similar to McAlpine, the approach to the locks is via a canal. Since the lock intakes are located in an embayment off of the river, the surges experienced at McAlpine are not a problem here. The unique footprint of the locks means that site specific plans must be developed for any capacity enhancement project.

Approach Time

The interval between the time a tow passes the lock arrival point and the time the two is prepared to enter the lock chamber is defined as the approach time. Traffic between the arrival point and the lock chamber is typically limited to one tow. This provides pilots with the maximum flexibility to maneuver and ensures safe utilization of the lock. The approach time can vary depending on the conditions at the lock with the average falling between thirty and forty minutes.

3.3.2 Culvert Valves

Each culvert in a filling and emptying system has two valves. The filling valve is located between the upper pool and the lock chamber and the emptying valve is located between the lock chamber and the lower pool. The valves are always the same size and

are only operated together during flushing operations. The two filling (or emptying) valves must be synchronized in F/E systems that utilize two culverts. All of the locks constructed since the opening of New Cumberland in 1959 use reverse tainter valves. Some of the locks on the upper reach of the river use butterfly valves. The stoney valve has been used on tributary streams.

Reverse Tainter Valves

The most common valve type in use at Ohio River Navigation Projects is the reverse tainter valve. The valve is a circular arc that is supported by two strut arms that are attached to anchorages via hinges. The valve requires a significant amount of space and is usually placed in an open pit within the lock wall. This pit serves as a surge tank during filling and emptying operations. The valves can be operated by cables connected to horizontal hydraulic cylinders, but the most common mechanism consists of a strut arm connected to a hydraulic cylinder through a bell crank assembly. The typical configuration is shown in Figure ED 3-2. For clarity sake, the bulkhead slots are not shown in the figure, they are located just upstream and downstream of the culvert valve pit as indicated by the arrows in the figure. The geometry of the operating mechanism results in a nonlinear relationship between hydraulic cylinder movement and valve opening. This characteristic proves to be beneficial during the early stages of filling or emptying when the discharge rate is changing rapidly.

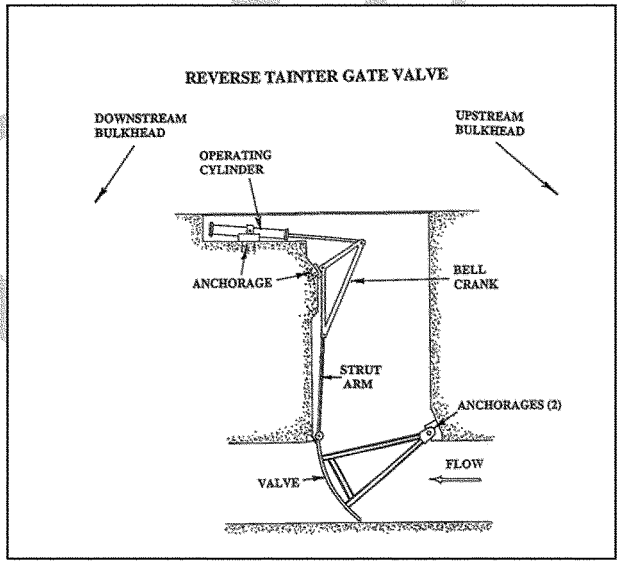

Figure ED 3-2. Typical F/E Valve for Ohio River Locks

Butterfly Valves

When combined with a central culvert filling and emptying system, the butterfly valve provides a cost effective means of flow control. The major disadvantage of this valve is associated with anticipated maintenance difficulties. A diagram of this type of valve is provided in Figure ED 3-3.

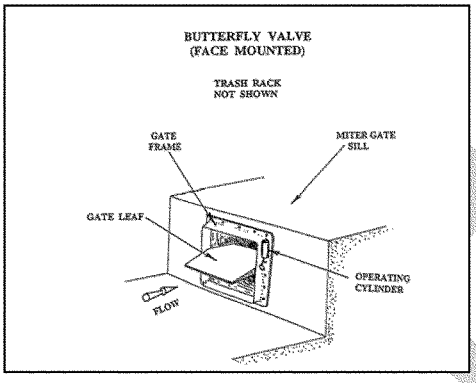

Figure ED 3-3. Butterfly Valve

Stoney Gate Valves

These vertical lift gates can be operated by hydraulic cylinders or hoists. Rollers on either side of the valve run in vertical raceways to reduce frictional forces. Ease of maintenance is achieved by locating the operating mechanism on the top of the lock wall. Another significant advantage is the smaller footprint that is required for the valve. The valve requires less space and the monolith required to support this type of valve is smaller. The operating scheme usually results in a linear valve opening. Careful consideration must be given to any design that incorporates this type of valve with a reverse tainter valve. A typical stoney valve is shown in Figure ED 3-4.

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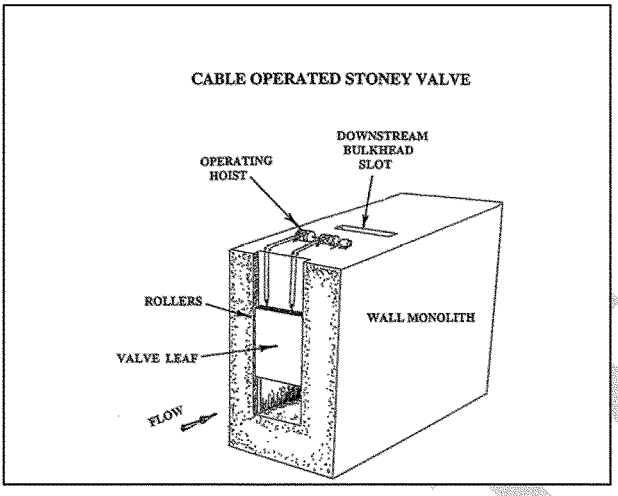

Figure ED 3-4. Stoney Gate Valve

3.3.3 Discharge Systems

Velocities near lock discharges are relatively high and the water surface tends to be violent. The outfalls are usually located riverward of the lock chamber so that the turbulent discharges do not interfere with navigation. The lower guard wall protects vessels and tows from the adverse currents and high velocities that are generated during lock discharges. Some of the locks in the inland waterways system have F/E systems that discharge into the lower approach area immediately downstream of the lock. This type of design places restrictions on tow movements in the lower approach, especially when the lock is discharging.

3.3.4 Hawser Force

When filling or emptying a lock chamber, small oscillations develop in the water surface within the lock chamber. The oscillations will tend to induce motion in a tow within the lock chamber. As a result, the tow must be moored with hawser lines to prevent it from striking the miter gates. These lines must be able to resist the forces generated by the moving tow. The resisting forces generated in the line are defined as hawser forces. These forces are usually evaluated with physical hydraulic models. Experience has indicated that limiting the hawser forces in a model to less than five tons will provide satisfactory prototype performance. Recent advances in numerical modeling techniques have provided additional methods for evaluating hawser forces. The numerical techniques provide satisfactory results for screening of alternatives, but final design should be based on the results of physical hydraulic model tests.

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In traditional F/E systems, the filling cycle will generate greater hawser forces than the emptying cycle. In addition, the most significant factor influencing the oscillations in the lock chamber is the rate of change of discharge (dq/dt). These factors produce the greatest hawser forces during the early part of the filling cycle while the valve is opening.

3.3.5 Chamber Empty / Fill Time

The system of intakes, culverts, valves, ports, and manifolds that is used to raise or lower the water level in the lock chamber is known as the lock filling and emptying (F/E) system. The design of these systems must optimize the solution of two mutually exclusive objectives. The lock must be filled or emptied as rapidly as possible without creating adverse oscillations in the lock chamber.

Typical F/E Systems

The three typical F/E systems used on the Ohio River are: side port, split lateral, and bottom lateral. These designs have been developed to accommodate various combinations of lock size and lift.

Side Port System

This system is commonly found in locks with lifts less than twenty five feet. The configuration features a large culvert in each of the lock walls. Intake manifolds are located in the face of the approach walls at a point upstream of the miter gates. Large valves located near the miter gate pintle control flow from the upper pool into the culverts. The culverts are connected to the lock chamber through a series of ports in along the face of the lock chamber wall. The valves that control emptying of the lock chamber are located downstream of the ports. The discharge section of the culvert leads from these emptying valves to the lower pool.

Split Lateral System

Projects with lifts in excess of thirty feet feature this type of F/E system. This configuration is similar to the side port system in that a large culvert is located in each lock wall. The filling valves are also typically located near the miter gate pintle. Instead of ports, each culvert is connected to the lock chamber through a series of lateral culverts. One culvert supplies the lateral field in the upper portion of the chamber and the other culvert supplies the lateral field in the lower portion. These lateral culverts extend from the main culvert across the lock chamber floor to the opposite lock wall. Each of the lateral culverts has a series of ports that allow flow to enter or exit the lock chamber. The valves that control emptying of the lock chamber are located downstream of the lateral culverts. The discharge section leads form the valve to the lower pool.

Bottom Lateral System

The 600-foot auxiliary locks on the Ohio River utilize this system. It is similar to the split lateral system except that there is only one culvert instead of two. Consequently, there is only one lateral field extending across the middle portion of the lock chamber. Since the culvert is the same size as the culverts for the main chamber, the valves and bulkheads are interchangeable. The discharge portion of the auxiliary lock passes underneath the main lock chamber so that it can discharge in the lower pool area away from the approach.

Central Culvert F/E System

Traditional F/E systems incorporate large culverts within the lock walls. New lock designs that incorporate roller compacted concrete and other construction materials and techniques cannot accommodate the culverts within the lock walls. As a result, the traditional F/E systems must be adapted to these new designs. The central culvert F/E system has twin culverts situated on the floor of the lock chamber away from the walls, but the culverts themselves are located in the lock walls for maintenance access.

3.4 DAM OPERATION

3.4.1 Stair Step

The locks and dams on the Ohio River were designed and operated on the "stair step" principle. The target elevation of the upstream pool is such that a minimum navigation depth of nine feet is provided at all times. The height of the dam gates has been set to meet this requirement. The lower miter gate sills of the locks are set to match the target elevation of the next downstream dam. During periods of low flow, the navigation pools are almost flat. This conditions results in the "stair step" profile as shown in Figure ED 4-1.

The dam gates of a project are operated such that the target elevation of the upper pool is maintained at the upstream face of the dam. This insures a minimum navigation depth of nine feet upstream of the project. During periods of moderate to high flow, the water surface upstream of each dam will develop a sloping profile starting at the upstream face of the dam and extending upstream to the next dam. As a result, a typical lock and dam on the Ohio River will have a relatively steady upper pool elevation and a fluctuating tailwater elevation.

If flows in the river increase substantially during a flood, the dam gates can be raised as needed until they are in the fully opened position. Under these conditions, the gates are clear of the water and the upper pool elevation can no longer be controlled. The natural flow of the river then becomes the controlling factor. If the level of the water continues to rise, it is due to the flow in the river and not the existence or operation of the project. A slight increase in pool elevation upstream of the dam may be observed due to

the project. This increase is similar to that which would be caused by bridge piers and does not have a significant impact on the water surface or flows in the river.

3.4.2 Hinged Pool Operation

A hinged pool operation differs from a stair step operation in that the target pool elevation is maintained at a location upstream of the dam. As the flow increases, the water surface at the upstream end of the pool rises and the water surface near the upstream face of the dam lowers. At the present time, the only hinge pool now in operation on the Ohio River navigation system is at Emsworth L/D. A two foot reduction of the upper pool elevation is used to reduce the duration of high water conditions at Pittsburgh's Golden Triangle. The Olmsted Dam, now under construction, will be operated in accordance with a complex hinged pool plan with four target locations upstream of the project. The most significant target point is located fifty two miles upstream of the dam site.

Da

Section 4

EXISTING OHIO RIVER NAVIGATION PROJECT CONDITION AND CONFIGURATION

4.1 GENERAL BACKGROUND INFORMATION

There are currently a total of 20 active lock and dam projects on the 981-mile reach of the mainstem Ohio River. Six of these projects in the upper reach are under the jurisdiction of the Pittsburgh District, six projects in the middle Ohio River are within the boundaries of the Huntington District, and the remaining eight on the lower end are controlled by the Louisville District. The vast majority of the projects have high lift, gated dams, although the type of dam gate varies by project. The only exceptions to this are Lock and Dams 52 and 53 on the extreme lower Ohio River and Dashields in the upper Ohio River. Dashields is a fixed crest concrete dam. The dams at 52/53 are controlled by boat-operated wickets. Lock and Dams 52/53 will be replaced once Olmsted Locks and Dam, currently under construction, is completed around 2014. For the purposes of ORMSS, it is assumed Olmsted will be active in 2014 and 52/53 are deactivated. Therefore, the Louisville District will have seven projects under their jurisdiction when that occurs. A plan and profile view of the projects on the Ohio River is depicted in Figure ED 4-1.

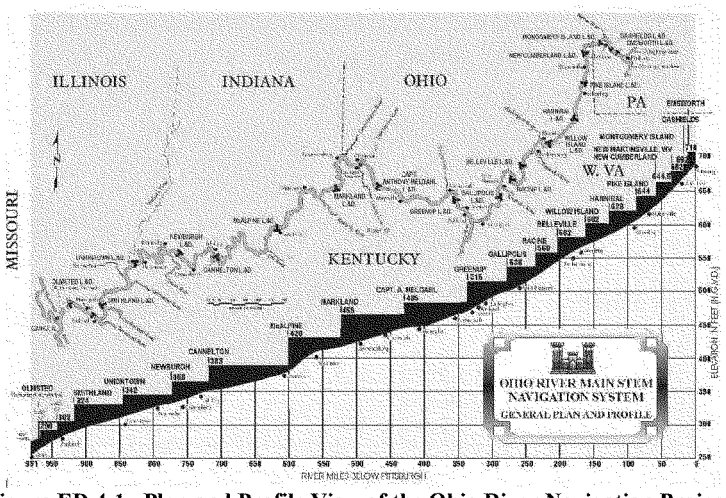

Figure ED 4-1. Plan and Profile View of the Ohio River Navigation Projects

The majority of the projects are configured with side-by-side 110' x 1200' main and 110' x 600' auxiliary lock chambers. There are a few exceptions to this typical configuration. These include the upper three projects (Emsworth, Dashields, and Montgomery) which have a 110' x 600' main chamber and 56' x 360' auxiliary chamber. There are a few projects on the lower Ohio River where traffic levels warrant more lock capacity. For example, the Smithland project has twin 110' x 1200' lock chambers. The Olmsted project will also have twin 110' x 1200' lock chambers once completed. Finally, a new 110' x 1200' lock chamber at McAlpine is currently under construction to replace the dilapidated 110' x 600' auxiliary chamber, so when completed McAlpine will also have twin 1200-ft lock chambers. The new lock at McAlpine is currently scheduled for completion around 2008.

4.2 GENERAL ASSESSMENT OF THE LONG-TERM NEEDS FOR THE OHIO RIVER NAVIGATION SYSTEM

There are two related major concerns associated with many of the navigation projects on the Ohio River. The first concern is the general long-term condition of many of the Ohio River projects given their age and high level of historical usage. Excluding the three lock chambers currently under construction (two at Olmsted and one at McAlpine) and L/D 52 and 53 which will be decommissioned, there are 35 lock chambers on the mainstem of the Ohio River. The average age of these lock chambers is 43 years. The service life of a lock and dam varies according to many factors including its operating environment, level of use, quality of original construction, but typically they are designed for a 50-year life without requiring increasing levels of maintenance to keep them operational. It should be noted that the Ohio River operates year round without seasonality, therefore, maintenance and large-scale repairs during the "off season" or "winter shutdown" period is not a viable option for this river system. Repairs need to be made while traffic continues to transit the system, therefore, extended lock closures are a major concern from an economic standpoint. The likelihood of more frequent, lengthy lock closures to make repairs increases as the projects age. This is evidenced by recent history on many Ohio River locks. The Ohio River navigation system is an extremely high usage system (both commercial and recreational usage) with roughly 270 million tons moving through the system annually. Some of the busiest locks in the world in terms of annual tonnage transit through Ohio River locks. Therefore, it is of great concern that roughly 54% of the existing lock chambers and dams on the Ohio River will exceed their original 50-year design life within the next 10 years. Several are already past their original design life.

The increasing usage and aging of the infrastructure is coupled with the second major concern, which is the existing capacity of the smaller auxiliary lock chambers relative to current and projected future traffic levels. At several sites, the existing traffic levels are near or exceed the capacity of the existing auxiliary chamber. Most tows are configured to lock through the longer, 1200-ft main chamber in order to maximize shipping efficiency. However, maintenance is required in order to keep these high use locks operating safely. The maintenance closure frequencies and durations vary by district according to their repair fleet operations, manpower availability, and number of projects requiring repairs by the fleet. The closures of the main chamber require the longer tows to lock through the shorter auxiliary chamber, which is typically 600-ft in

length at most Ohio River projects. In order to lock through the shorter auxiliary lock chamber, the tow must be reconfigured into two shorter segments to process through the auxiliary lock. This process is called "double-cutting" since it takes two cuts for most tows to process through the lock. This causes a large queue of tows waiting to process through the facility since it dramatically slows the transit process. Typically, the transit time (approach, locking, and departure) through an Ohio River project takes approximately an hour when both the main and auxiliary lock chambers are open. When the main chamber is closed for lengthy periods, the delay for some tows can reach several days depending upon the individual characteristics of the closure. This causes millions of dollars in navigation delay to the towing industry and thus, the general population depending upon the commodity that is shipped.

Figure ED 4-2 depicts an October 2001 aerial photograph of the queue of tows waiting to process through the John T. Myers Locks and Dam while the main chamber is dewatered for maintenance. Note the accumulation of tows waiting immediately at the facility, three at the lock, one waiting on the downstream bank, and 5 waiting upstream in of the project. In addition, tows tie up both upstream and downstream on the bank line of the project for several miles during these delays stirring up the bank line that causes adverse environmental effects. Tows can sometimes be delayed up to several days during main chamber outages depending upon the project site, main chamber outage duration, and towing industry reaction to the closure. Note that tow costs are approximately $450 per hour and 15-20 may transit through a facility during non-closure periods. Therefore, delay costs add up quickly under this scenario.

It should also be noted that these delays described above are encountered for "planned" maintenance closures where the towing industry is given a significant lead time indicating when lock chambers are planned for closures so they can make appropriate shipping modifications as necessary. Unexpected closures are anticipated in the future as individual project reliability degrades as major structures age and see more usage cycles. There are several Ohio River projects where the reliability of major components (lock gates, filling/emptying valves, mass concrete, etc…) is a major concern as several projects are presently approaching their original design life. In addition, the ORMSS is investigating the long-term performance through 2060 in which many projects will be near or over 100 years in age with high usage. Therefore, the reduced auxiliary chamber capacity coupled with reduced reliability of major components plays a major part in the overall economic analysis of the ORMSS.

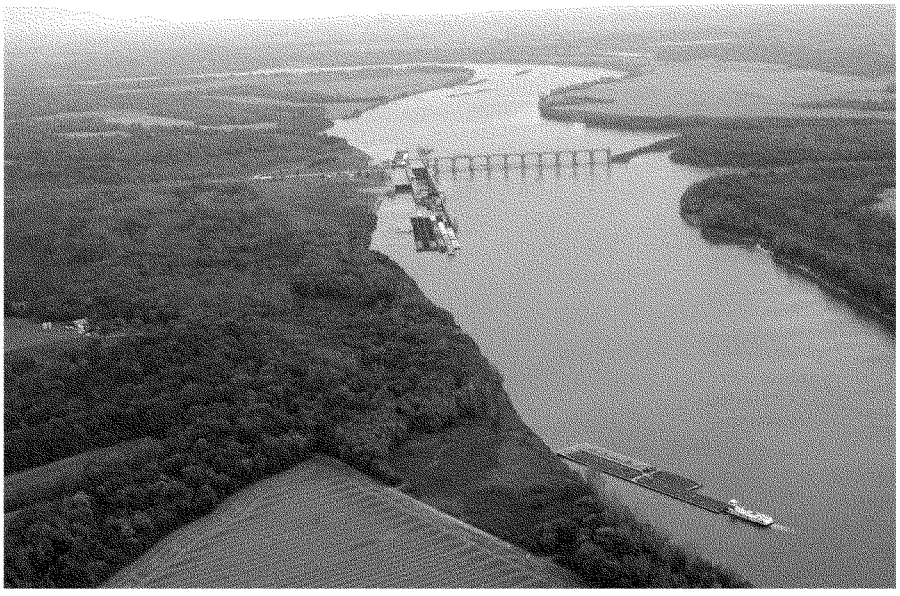

Figure ED 4-2. Recent J.T. Myers Main Chamber Dewatering with Tow Queue

4.3 EMSWORTH LOCKS AND DAM

4.3.1 Project Information - Emsworth

Emsworth Locks and Dam (L&D) was authorized by the Secretary of the Army on 18 July 1918 under the authority of Section 6 of the River and Harbor Act approved 3 March 1909, as replacement for Ohio River Locks and Dams No. 1 (Davis Island Lock and Dam), built 1877-1885 and Lock and Dam 2, built 1898-1906. The project was constructed from 1919-1922, and placed in operation in September 1921. Emsworth L&D is under the jurisdiction of the Pittsburgh District.

Emsworth L&D is located 6.2 and 6.8 river miles downstream of Pittsburgh, Pennsylvania (main and back channel dams). It is 7.1 miles upstream of Dashields L&D. The navigation locks are located on the right bank of the Ohio River (main channel). The pool extends from the Emsworth Dam to the Braddock L&D, located at river mile 11.2 on the Monongahela River, and to L&D 2, located on the Allegheny River. The length of the Emsworth pool is 17.4 river miles (Monongahela River side), and 12.9 river miles (Allegheny River side). The port of Pittsburgh lies along the Emsworth pool. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation Pools relative to the Emsworth project. Emsworth L&D provides an 18.0 ft. lift, from the Dashields pool (normal pool elevation 692.0) to the Emsworth pool (normal pool elevation 710.0 Emsworth L&D replaced L&D 1 (Davis Island L&D) at river mile 4.7. Davis Island L&D was built 1877-1885, and was the first moveable dam (wickets) in the United States. The main and back

channel dams were originally constructed in 1919-1922 as fixed crest structures. The dams were reconstructed in 1935-1938 to provide gated crests, thereby raising the Emsworth pool by 7.0 feet, and allowing for elimination of L&D 1, Allegheny River, built 1894-1902, and L&D 1 Monongahela River, reconstructed 1909-1915.

4.3.2 Project Layout - Emsworth

The Emsworth project features two lock chambers with a non-navigable, gated dam on both the main and back channels of the Ohio River. The Emsworth Dam is composed of 8 gate bays (main channel) and 6 gate bays (back channel). The main channel dam contains a short fixed weir, located adjacent to the river wall. Thirteen of the fourteen gates on the Emsworth dams are vertical lift. One gate bay (No. 9, or the first gate bay on the back channel dam) utilizes a Sidney gate, which is a "hybrid" gate (cross between a vertical lift and a tainter gate). Emsworth does not have a hydroelectric plant. A recent aerial photograph is shown in Figure ED 4-3 and a site plan/vicinity map is shown in Figure ED 4-4 to give the reader a better feel of the project's characteristics.

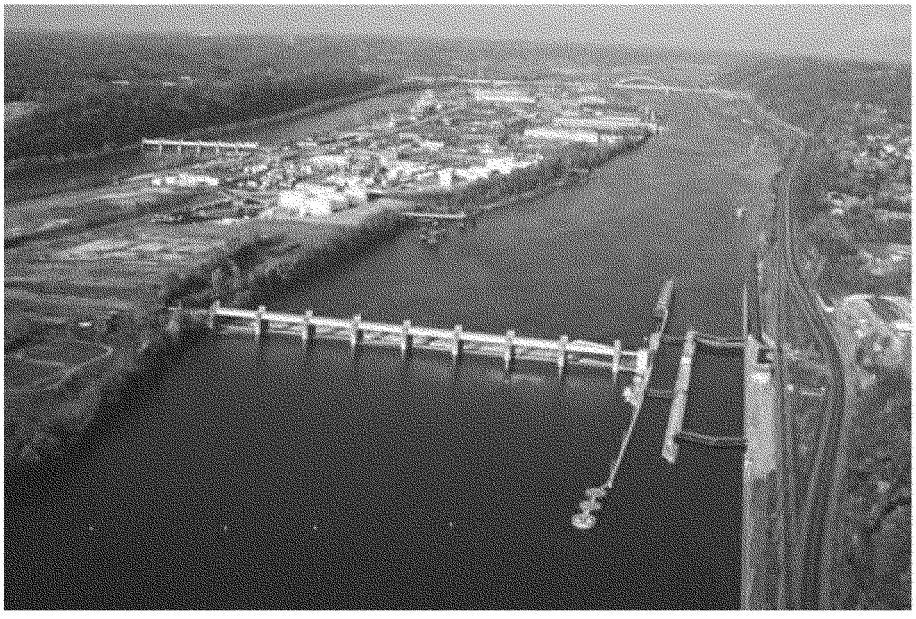

Figure ED 4-3. Aerial View of the Emsworth L&D Project

Two adjacent parallel locks are located on the right bank of the Ohio River. The main lock chamber has clear dimensions of 110' x 600' and the auxiliary lock 56' x 360'. The auxiliary lock is located riverward of the main lock. Filling and emptying systems are designed to fill and empty the locks in six to eleven minutes for each of these operations. The main lock is filled and emptied through a series of butterfly valves in the upper and lower middle wall. The auxiliary lock fills and empties thru a series of

butterfly valves in the upper and lower river wall. Both chambers can be dewatered by use of poiree (needle) dams, located immediately upstream or downstream of the miter gates in each chamber. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sill, lock wall monolith, lock chamber monolith, and miter gate monolith.

The dams were originally constructed as non-navigable fixed-crest structures. Both main and back channel dams were later reconstructed to provide gated-crests and raise Emsworth pool by 7.0 feet. The overall length of the dams are 967.42 feet (main channel) and 750.0 feet (back channel). The main channel dam consists of 8 gated bays, each 100 feet in length, with a concrete weir adjacent to the river wall. The back channel dam consists of 6 gated bays, each 100 feet in length. Thirteen of the fourteen gated bays utilize vertical lift gates. Only one gate bay (No. 9), the first bay on the back channel dam utilizes a Sidney gate. All fourteen gates are non-submersible.

Both main and back channel dams contain service bridges, which supports both a bulkhead crane (below) and a maintenance crane (on top). The bulkhead cranes run along a crane runway, attached to the underside of the service bridges, transferring bulkheads from the storage pits at the ends of the dams, to any of the gate bays, as needed. Three bulkheads are stored at each dam and are fabricated to "stack" on top of each other to provide closure for one gate bay.

Normal upper pool (Emsworth pool) is elevation 710.0 mean sea level. Normal lower pool (Dashields pool) is elevation 692.0 mean sea level. Thus, the lift is 18 feet at normal pool levels.

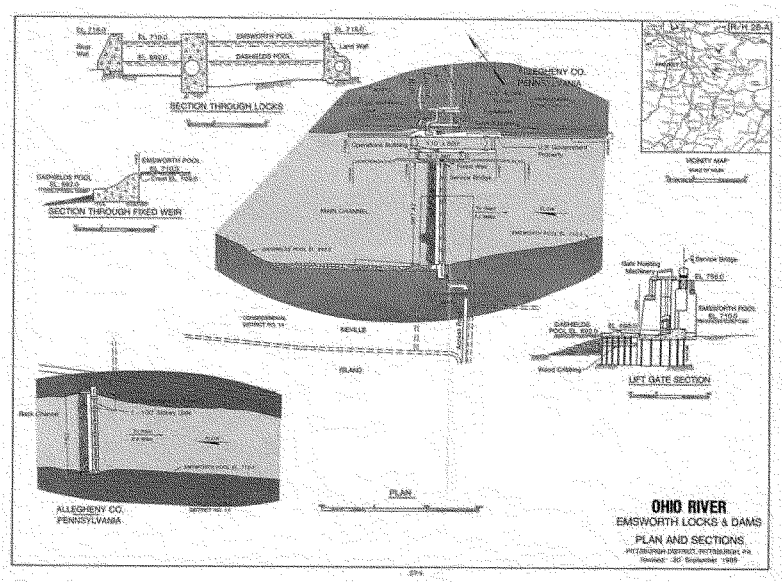

Figure ED 4-4. Plan View and Vicinity Map of the Emsworth L&D Project

4.3.3 Assessment of Concerns and Needs - Emsworth

The Emsworth lock and dam project plays a major role in the economy of the Pittsburgh region, since the Emsworth dams create and control the pool which flows adjacent to the city of Pittsburgh and it's adjoining communities. An issue of concern is the structural deficiencies of the vertical-lift dam gates, which limits the capacity of the dam to control pool elevations under extreme flow conditions. The facilities are situated in a highly industrialized area with many of the industrial plants relying heavily on water transportation for the receiving of raw materials and the shipping of finished products. Should the lift gates of the dam and/or lifting machinery fail, the resulting loss of pool would be catastrophic with the above mentioned industrial complex's dependence on water transportation. In addition, power plants and industrial and municipal water intakes which rely on relatively stable pools would be adversely affected. Two of the 14 dam gates have become inoperable due to reported deficiencies. One of these gates and machinery (gate bay No. 6) have been removed and replaced in 2002. The new gate is raised and lowered with hydraulic-operated cylinders. To date, performance of the new gate and machinery has been extremely reliable. The Pittsburgh District has prepared a Rehabilitation Evaluation Report, addressing the reliability and needs of the Emsworth Main Channel and Back Channel Dams. This RER performs an economic justification of a major rehabilitation of the Emsworth Dam, showing that anticipated federal construction costs are justified. The project was approved in 2002, but remained unfunded until start-up funds were initiated due to the concern about the condition of the dam. Refer to the Emsworth Dam Rehab Report, dated July 2001 and Addendum to the Emsworth Dam Rehab Report, dated December 2001. The Addendum addresses the issue of scour and accompanying problems and needs. The major rehab project of the dam is currently in construction and should be completed within the next few years.

Internal cracking in concrete lock wall monoliths is another significant concern and need at Emsworth. Numerous randomly-located cracks are prevalent throughout most concrete monoliths, throughout the land wall, middle wall, river wall, guide walls and guard walls. This cracking is known as a result of numerous cores drilled throughout the walls, as well as visual inspections throughout the horizontal and vertical surfaces as well as throughout the recesses and galleries. Cracking tends to propagate if left unchecked. Internal stresses created by freeze-thaw cycles is a major driver in crack growth. Cracking can eventually propagate through entire wall sections and lead to separation and significant movements of varying-sized monolith sections. A diagram graphically showing failure potential failure scenarios is shown in Figure ED 4-5.

The main causes of concrete deterioration for the locks and dams are from weathering and freeze-thaw action. Due to the fact that the locks and dams were constructed before the advent of air-entrainment in concrete, the concrete has been particularly susceptible to weathering and freeze-thaw damage. Construction practices in the 1920's and 1930's were rather poor compared to the quality control tolerances which are required for a similar project constructed today. Some construction seasons extended into the winter months, with little or no protection of the newly placed concrete from the elements. Prior to the major rehabilitation effort in the mid 1980's, horizontal and vertical surfaces of the lock walls were in advanced stages of deterioration. At Emsworth, the vertical and horizontal extent of concrete deterioration measured from the top and chamber face of the lock walls was up to 4.5 and 1.5 feet, respectively. The

major rehabilitation projects detailed varying levels of horizontal and vertical wall repairs. As stated previously, these repairs were performed in order to extend the useful life of the projects for another 25 years. These horizontal concrete overlays and vertical refacing of the lock chamber walls are considered cosmetic in nature and do not address the underlying problems associated with the deteriorated state of the existing concrete. The overlays and refacing only superficially delay the advent of further concrete deterioration.

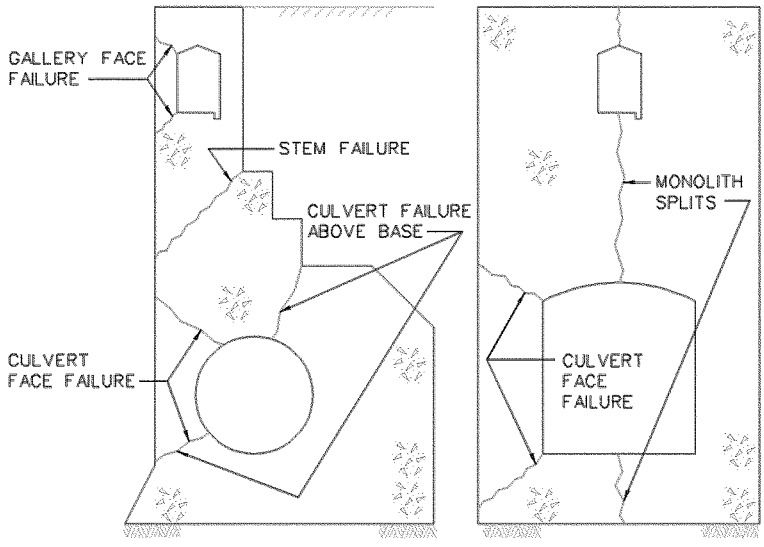

Figure ED 4-5. Internal Cracking in Lockwall Monoliths Typical for Emsworth, Dashields and Montgomery L/D's

4.3.4 Major Rehabilitation Project - Emsworth

Emsworth L&D has undergone major rehabilitation during the early1980's. These major rehabilitation efforts were designed to extend the useful life of the structure and maintain a safe navigation system for commercial and recreational users. Both 50 year and 25 year plans were considered. For all three rehabilitation efforts the 25-year plan was chosen for the following reasons; (1) feasibility to perform the required work in terms of construction time and adaptability to existing lock walls. The 25-year plan would require a significantly shorter construction period with less impact to the navigation industry. Furthermore, utilizing the existing "footprints" of the lock walls would not be conducive to retrofitting components, designed to conform to modern criteria, to extend the life of the structure for 50-years. (2) the lower cost needed to perform the 25-year plan versus the 50-year plan, and (3) the 25-year plan was a stop gap measure intended to allow safe operation of the project until replacement of the lock structures would be programmed sometime near the end of this period. With these

factors in mind, this condition report outlines the condition of the major features of the locks and dams, noting that the 25-year time period from the end of the major rehabilitation projects for Emsworth, Dashields, and Montgomery would occur at years 2010, 2015 and 2014, respectively.

4.4 DASHIELDS LOCKS AND DAM

4.4.1 Project Information - Dashields

Dashields Locks and Dam (L&D) was authorized by the Secretary of the Army on 18 July 1918 under the authority of Section 6 of the River and Harbor Act approved 3 March 1909. The project was constructed from 1927-1929, and placed in operation in August 1929. Dashields L&D is under the jurisdiction of the Pittsburgh District.

Dashields Locks and Dam is located 13.3 miles downstream of Pittsburgh, Pennsylvania . It is 7.1 miles downstream of Emsworth L&D. The towns of Edgeworth, Sewickley, Osborne, Coraopolis, Haysville, Glenfield, Dixmont and Emsworth lie along the Dashields pool. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation Pools relative to the Dashields project. Dashields L&D provides a 10.0 ft. lift, from the Montgomery pool (normal pool elevation 682.0) to the Dashields pool (normal pool elevation 692.0).

4.4.2 Project Layout - Dashields

The Dashields project features two lock chambers with a non-navigable, fixed-crest dam. The Dashields Dam is composed of 8 gate bays (main channel) and 6 gate bays (back channel). The main channel dam contains a short fixed weir, located adjacent to the river wall. Thirteen of the fourteen gates on the Emsworth dams are vertical lift. One gate bay (No. 9, or the first gate bay on the back channel dam) utilizes a Sidney gate, which is a "hybrid" gate (cross between a vertical lift and a tainter gate). Dashields does not have a hydroelectric plant. A recent aerial photograph is shown in Figure ED 4-6 and a site plan/vicinity map is shown in Figure ED 4-7 to give the reader a better feel of the project's characteristics.

Two adjacent parallel locks are located on the right bank of the Ohio River. The main lock chamber has clear dimensions of 110' x 600' and the auxiliary lock 56' x 360'. The auxiliary lock is located riverward of the main lock. Filling and emptying systems are designed to fill and empty the locks in six to eleven minutes for each of these operations. The main lock is filled and emptied with one 13 ft. by 14 ft-10 in. butterfly valve located both in the upper and lower land and middle walls. The auxiliary lock fills and empties with one 10 ft. by 12 ft. butterfly valve, located in the upper end (filling) and lower end (emptying) of the river wall. Both chambers can be dewatered by use of poiree (needle) dams, located immediately upstream or downstream of the miter gates in each chamber. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sill, lock wall monolith, lock chamber monolith, and miter gate monolith.

Figure ED 4-6. Aerial View of the Dashields L&D Project

The dam is the only fixed crest (uncontrolled flow) structure built along the entire Ohio River. The dam is unreinforced concrete founded on rock and provided with a shear key into rock near the upstream face. The overall length of the dam is 1,585 ft. and crest elevation is 692.0. The fixed crest dam section extends from the river wall to the abutment (on the right bank) and contains no gated sections, service bridge, bulkhead or maintenance cranes.

Normal upper pool (Dashields pool) is elevation 692.0 mean sea level. Normal lower pool (Montgomery pool) is elevation 682.0 mean sea level. Thus, the lift is 10 feet at normal pool levels.

4.4.3 Assessment of Concerns and Needs - Dashields

Unstable guide walls coupled with heavily cracked lockwall concrete contribute to serious condition concerns at Dashields. Analysis of upper and lower guide wall stability has confirmed that the walls are unstable. Survey monitoring has revealed movement in both walls. Failure of the guide wall monoliths could block the approaches to the land chamber and disrupt river traffic. An unscheduled outage of the main chamber would force all traffic, including double cut tows, to lock thru the auxiliary chamber, resulting in significant delays, even with the use of helper boats. Concrete cracking is extremely prevalent throughout the monoliths on the land, middle and river walls, and can be easily seen throughout the pipe galleries. Figures ED 4-8 and ED 4-9 show some the extent of some of the concrete damage to the approach walls at Dashields.

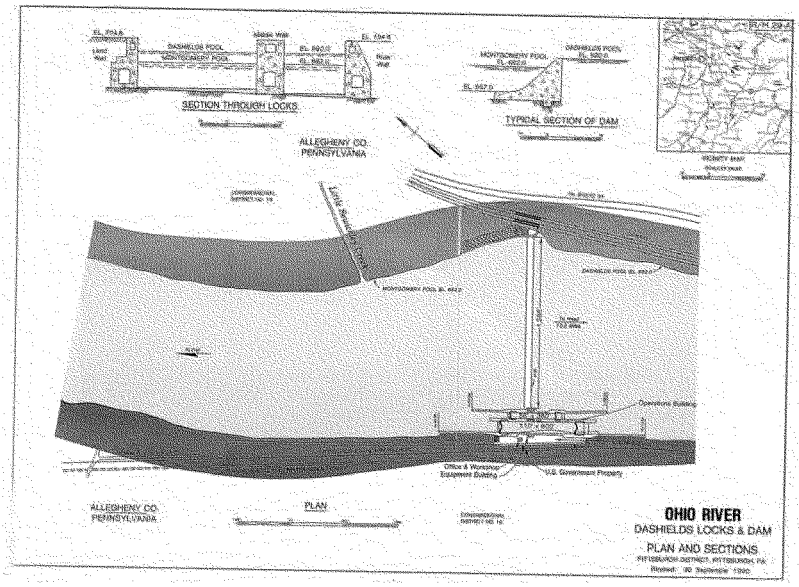

Figure ED 4-7. Plan View and Vicinity Map of the Dashields L&D Project

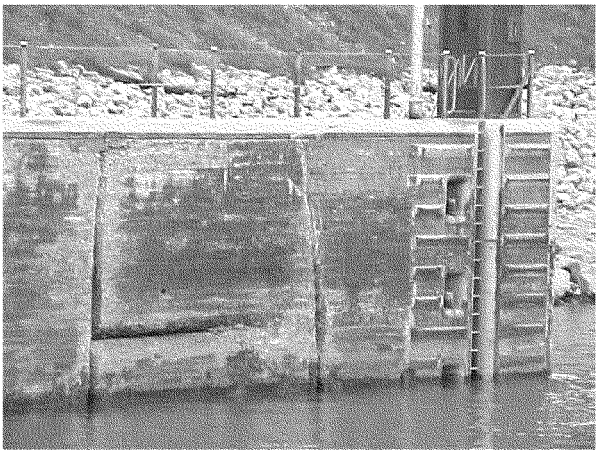

Figure ED 4-8. Lower Guide Wall – Downstream End as Seen From the River Wall

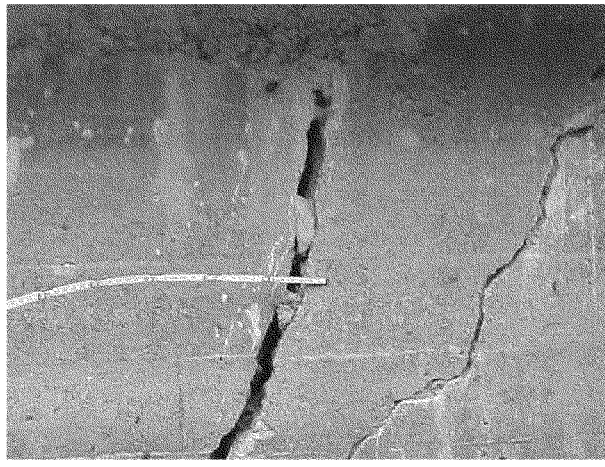

Figure ED 4-9. Upstream Guide Wall, Crack in Land Side Face of Wall

The main causes of concrete deterioration for the locks and dams are from weathering and freeze-thaw action. Due to the fact that the locks and dams were constructed prior to 1950, before the advent of air-entrainment in concrete, the concrete has been particularly susceptible to weathering and freeze-thaw damage. Construction practices in the 1920's and 1930's were rather poor compared to the quality control tolerances which are required for a similar project constructed today. Prior to the major rehabilitation effort for the upper Ohio projects completed 15 to 20 years ago, horizontal and vertical surfaces of the lock walls were in advanced stages of deterioration. The major rehabilitation projects detailed varying levels of horizontal and vertical wall repairs. These horizontal concrete overlays and vertical refacing of the lock chamber walls are considered cosmetic in nature and do not address the underlying problems associated with the deteriorated state of the existing concrete. The overlays and refacing only superficially delay the advent of further concrete deterioration.

Prior to the rehabilitation projects, the concrete at Dashields was the worse condition both from a deterioration standpoint as well as experiencing numerous cracking of a structural nature. Both Dashields and Montgomery locks utilize integral filling and emptying culverts and pipe galleries in all three walls. These features result in thin-walled sections with numerous reentrant corners, susceptible to stress concentrations, causing cracking and crack propagation. These details coupled with the lack of concrete reinforcing, which would be provided in modern structures, encourage conditions susceptible to cracking. Progressive riverward movement of the upper and lower guide walls continue to be monitored. A recent stability report recommended anchoring to retard the riverward movement.

The lock structure continues to be plagued by interior cracking, located at numerous random positions along the monoliths, but prevalent throughout the filling and emptying valve recesses, bulkhead recesses and miter gate machinery recesses. Several structural repairs were performed during the major rehabilitation project. Recently a structural crack has been identified at the downstream land wall culvert valve recess propagating through to the valve bulkhead recess. Due to the age of the underlying

original concrete, typical for all three locks and dams, freeze-thaw cycles have caused cracking and deterioration along weather-susceptible surfaces, such as recesses which are covered with aluminum grating. In some cases, such as cracking in the miter gate anchorage areas, fatigue appears to have contributed to the deficiencies. Typical concrete damage photos of the lock structure at Dashields are shown in Figures ED 4-10 and ED 4-11.

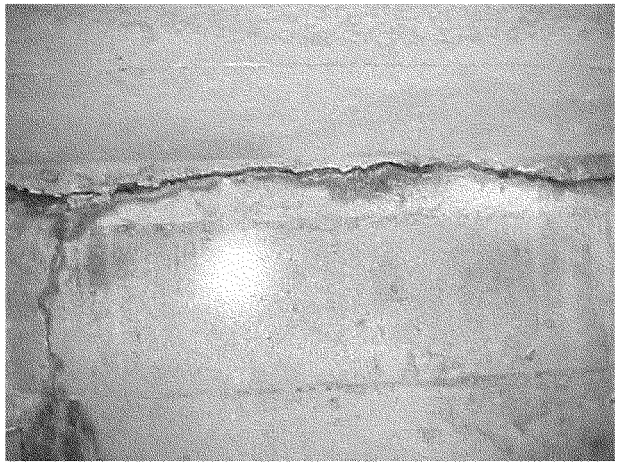

Figure ED 4-10. Cracking in River Wall Gallery at Monolith R-20

Figure ED 4-11. Cracking in Middle Wall Gallery

Dashields underwent major rehabilitation during the late 1980's. These major rehabilitation efforts were designed to extend the useful life of the structure and maintain a safe navigation system for commercial and recreational users. The 25-year

rehabilitation plan was chosen for the same reasons as those outlined for the Emsworth rehabilitation. This 25 year design plan extended the life expectancy from 1989 to 2014 at Dashields.

There are no significant navigation problems; however, industry considers the lock approaches to be difficult to maneuver with larger tows, due largely to the location of ports along the upper and lower guard walls, which has a tendency during filling or emptying to create turbulence in the approach areas. Dashields has an extensive history of tow damage to the miter gates, further indicating a less than desirable approach condition in part due to the ported design.

The Dashields project is one of the older projects on the Ohio River, along with Emsworth, Montgomery, and McAlpine, built prior to World War II. The Dashields project began lockages in 1929.

The lock chamber sizes, 110' x 600' and 56' x 360' were once optimum for the size and configuration of Ohio River tows, but are now well below the size required to accommodate larger more powerful modern tows. The double lockage requirement consumes both time and additional operational wear and tear on both the lock structure and operating machinery. Also, the inadequate chamber sizes of these three locks deter economic activity vital to the region.

The Dashields dam has been plagued by scour problems over the years; hence, is another area of concern. Downstream scour holes and undermining of the dam apron have been detected. Annual dive inspections monitor these downstream conditions. A model study by ERDC was conducted prior to the rehab, to determine a method to eliminate the scour. As part of the major rehabilitation effort, tremie concrete and grout-filled bags were placed along the toe of the apron to impede the recurring scour along the base of the toe. Periodic dive inspections provide information that allows the District to monitor the adequacy of this repair.

4.5 MONTGOMERY LOCKS AND DAM

4.5.1 Project Information - Montgomery

Montgomery Locks and Dam is located 31.7 river miles downstream of Pittsburgh, Pennsylvania. It is 18.4 miles downstream of Dashields L&D. The pool extends 18.4 miles, from the Montgomery Dam, at river mile 31.7 to the Dashields dam, at river mile 13.3. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation Pools relative to the Montgomery project. Montgomery L&D provides a 17.5 ft. lift, from the New Cumberland pool (normal pool elevation 664.5) to the Montgomery pool (normal pool elevation 682.0).

4.5.2 Project Layout - Montogmery

The Montgomery project features two lock chambers with a non-navigable, gated dam on the Ohio River. The Montgomery Dam is composed of 10 gate bays. Two fixed weirs, on either end, were constructed as a part of the Montgomery dam. Each of the 10 gates are vertical lift. Montgomery does not have a hydroelectric plant. A recent aerial

photograph is shown in Figure ED 4-12 and a site plan/vicinity map is shown in Figure ED 4-13 to give the reader a better feel of the project's characteristics.

Two adjacent parallel locks are located on the left bank of the Ohio River. The main lock chamber has clear dimensions of 110' x 600' and the auxiliary lock 56' x 360'. The auxiliary lock is located riverward of the main lock. Filling and emptying systems are designed to fill and empty the locks in six to eleven minutes for each of these operations. The main lock is filled and emptied through a butterfly valve in the upper and lower middle wall. The auxiliary lock fills and empties thru a butterfly valve in the upper and lower river wall. Both chambers can be dewatered by use of poiree (needle) dams, located immediately upstream or downstream of the miter gates in each chamber. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sill, lock wall monolith, lock chamber monolith, and miter gate monolith.

The dam consists of 10 gated bays, each 100 feet in length, with two concrete weir sections, one adjacent to the river wall and the other adjacent to the abutment. The overall length of the dam, river wall to abutment, is 1,378.75 ft. Each of the 10 gate bays utilize vertical lift gates. All dam gates are non-submersible.

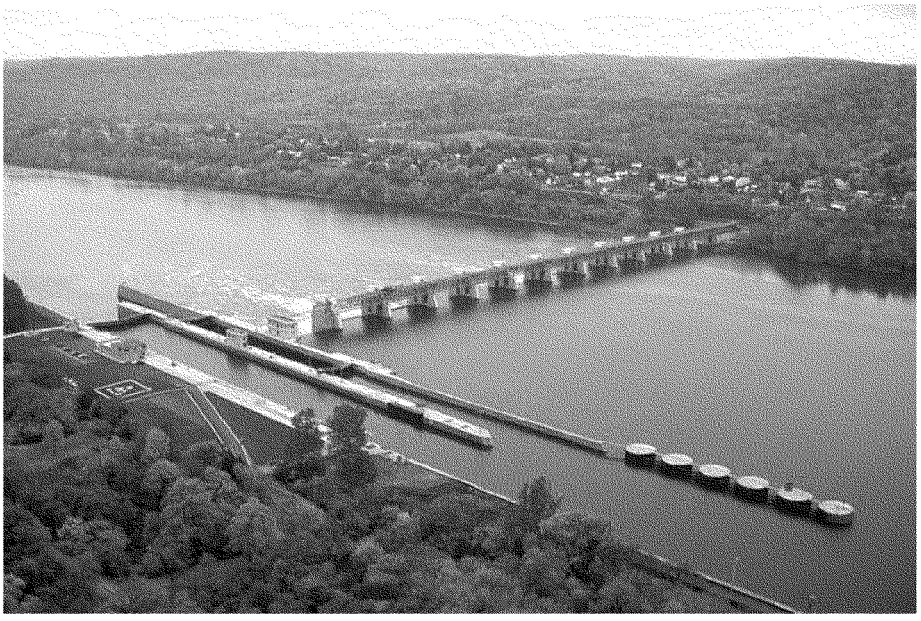

Figure ED 4-12. Aerial View of the Montgomery L&D Project

The dam was constructed with a service bridge, which supports both a bulkhead crane (below) and a maintenance crane (on top). The bulkhead crane runs along a crane runway, attached to the underside of the service bridge, transferring bulkheads from the storage pit at the ends of the dam, to any of the gate bays, as needed. Three bulkheads are stored at each dam and are fabricated to "stack" on top of each other to provide closure for one gate bay.

Normal upper pool (Montgomery pool) is elevation 682.0 mean sea level. Normal lower pool (New Cumberland pool) is elevation 664.5 mean sea level. Thus, the lift is 17.5 feet at normal pool levels.

4.5.3 Assessment of Concerns and Needs - Montgomery

Montgomery locks and dams is one of the oldest operating structures in the Pittsburgh District and has several concerns. Heavily cracked lockwall concrete and dam gate hoist problems are among the most severe. Concrete cracking is extremely prevalent throughout the monoliths on the land, middle and river walls, and is readily visible throughout the pipe galleries and within recesses (gate, valve, bulkhead, and ladder ways). Figures ED 4-14 and ED 4-15 depict typical concrete damage noted at Montgomery.

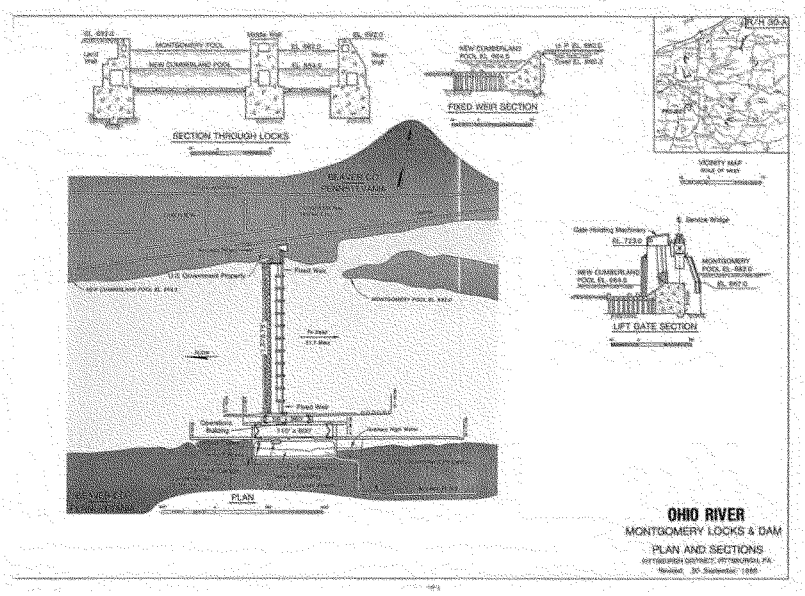

Figure ED 4-13. Plan View & Vicinity Map of the Montgomery L&D Project

The main causes of concrete deterioration for the locks and dams are from weathering and freeze-thaw action. Due to the fact that the locks and dams were constructed prior to 1950, before the advent of air-entrainment in concrete, the concrete has been particularly susceptible to weathering and freeze-thaw damage. Prior to the major rehabilitation effort, horizontal and vertical surfaces of the lock walls were in advanced stages of deterioration. The major rehabilitation projects detailed varying levels of horizontal and vertical wall repairs. As stated previously, these repairs were performed in order to extend the useful life of the projects for another 25 years. These horizontal concrete overlays and vertical refacing of the lock chamber walls are considered cosmetic in nature and do not address the underlying problems associated

with the deteriorated state of the existing concrete. The overlays and refacing only superficially delay the advent of further concrete deterioration. Furthermore, the overlays and refacing , which these feature of work were completed in 1987 , have experienced numerous cracking, therefore, consequently not providing the level of protection anticipated to achieve the 25 year design life expectancy. The lockwalls contain numerous cracks at numerous random locations, some of which begin at gate, valve and bulkhead recess corners and extend laterally or longitudinally throughout the entire monolith, and beyond. Many of these cracks have propagated downward into the pipe galleries, and likely are growing further toward the culverts. Pipe galleries in the land, middle and river walls are full of cracks, many with heavy efflorescence, indicating water penetration from above surfaces. Maintenance has regularly resealed cracks to prevent seepage, but is short lived. Under-reinforced monoliths (relative to today's standards) coupled with thin wall sections and lack of fillets along the gallery corners has been susceptible to torsion effects of wall loadings from pool fluctuations and dewaterings. Results are severe cracking throughout. Core samples have been taken in high-stress and other key areas to survey the extent of the problem. Many cores contain numerous cracks, at various elevations. Monoliths are at risk for this cracking to extend to exterior surfaces, causing separation of wall segments.

Montgomery L&D also has undergone a 25-year major rehabilitation during the mid 1980's. These major rehabilitation efforts were designed to extend the useful life of the structure and maintain a safe navigation system for commercial and recreational users. The same reasons for rehab and selection of the 25-year plan as was described for Emsworth and Dashields were applicable for Montgomery.

The gate hoists on the dam are a serious concern at Montgomery. The condition of the chains, and gate position indicators and two drive motors, one on each pier, creates a serious situation. The dam gate hoist chains tend to kink and are showing other signs of wear and lack of internal lubrication. The gate position indicators are driven by the hoist machinery and do not directly read the position of the gate. If a hoist chain were to kink or foul, the position indicator would not yield an accurate reading. Maintaining a level gate position is critical to safe dam operation. If a dam gate were to become jammed, part of the hoist machinery could fail and drop or jam the gate. The use of two drive motors in lifting the gate can create a large force. Due to these conditions, the dam is rarely operated remotely, even though programmable logic controllers (PLC's) were installed during the major rehabilitation. A more detailed evaluation of the dam gate hoist chains and sprockets should be made. Also, a more positive and reliable method of determining the gate position should be evaluated. Until the condition of the dam gate hoist machinery can be ascertained all mote operations of the dam gates should be discontinued.

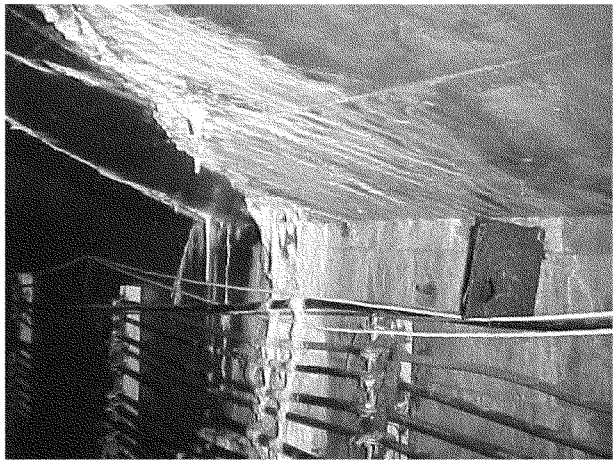

Figure ED 4-14. Typical Cracking, Efflorescence Throughout the Galleries

Figure ED 4-15. Typical Cracking, Efflorescence Throughout the Galleries

Stability analysis on the Montgomery lock walls, prior to the rehab, revealed that, in general the lock wall monoliths failed to meet criteria standards. The geometry of several major features of the locks, such as the upper guide wall and miter sill, whose configuration are of an unconventional nature, contribute to their structural inadequacies. Pre-stressed tensioning anchors, which are much more desirable than passive anchors, for enhancing stability of the monoliths, were not chosen due to various concerns from the Ohio River Division office. Statements were made from Division, commenting on the District's June 1980 Rehabilitation Report, indicating reluctance in using tensioned

anchors. "The entire anchoring scheme needs to be more fully developed and carefully reviewed to insure that the structure can withstand the loads that will be imposed by the anchors and that the anchors would be practical to construct." "In general, it is felt that the moderately large tendon anchors are not well suited to the anchorages proposed. They are located near the face of concrete and in thin concrete sections. They will be difficult to install and will overstress the concrete in tension in some areas and in compression in others. It may be necessary to use passive or lightly prestressed cement grouted prestressing bars (singularly or in bundles)". Consequently, passive anchors were installed in lieu of tensioned anchors, even though passive anchors contribute to the structural integrity of a monolith only after movement has occurred. Use of passive anchors is not recommended by current guidance within ETL 1110-2-310, "Stability Criteria for Existing Concrete Navigation Structures on Rock Foundations". Paragraph 8. States that "Non-prestressed anchors shall not be used if other options are feasible. The effectiveness of this system is questionable and undependable due to the movement required to activate the anchor force. Therefore, the system; should not be considered as effective in improving the safety factor for the structure's stability. They may be used as a last resort to prevent any possibility of catastrophic failure. In designing the passive anchors, uplift forces within the foundation were assumed to be reduced by the anchor force provided; however, the anchor force was recognized as not being fully active until sufficient movement between the foundation and the wall had occurred. The simplistic assumption that the anchors were active avoided a more complex analysis whereby the movement to mobilize the anchors would redistribute the uplift forces within the foundation. The incorrectness within the analysis probably would necessitate an adjustment whereby additional anchors would be provided and would further support the contention made that the installed passive anchors can not be depended on to provide the required factors of safety.

Montgomery dams have had a history of scour related problems exposing the downstream face of the dam, cribbing foundation, and wood piles and at times undermining the stilling basin. When the dam was being constructed a cofferdam washout occurred prompting the need to place stone fill along approximately 173 feet of the main channel dam. The stone and concrete blocks that were placed at the time of the washout also washed downstream in the following years. To stabilize the downstream face of the dam, stone filled barges were sunk along the downstream face and stone protection placed between them and the downstream face of the stilling basin in the summer of 1925. Placement of additional scour protection below the dam has been an ongoing maintenance concern. Additional placement of scour protection was performed during the major rehabilitation project. Subsequent to that effort, additional scour has occurred prompting the need to perform further measures to retard this adverse effect.

4.6 NEW CUMBERLAND LOCKS AND DAM

4.6.1 Project Information – New Cumberland

The project is located on the Ohio River, 54.4 river miles downstream from Pittsburgh, PA. The locks are at Stratton, Ohio, and the dam abutment is approximately 2.5 miles north of New Cumberland, West Virginia. It is the fourth navigation facility

from the head of the River at Pittsburgh. Tail water is controlled by Pike Island Lock and Dam, located at river mile 84.2.

4.6.2 Project Layout – New Cumberland

The dam is 1315 feet long with eleven gated bays of 110 feet each, and 12 piers. Flow is controlled with six non-submergible tainter gates and five submergible tainter gates. Target pool is elevation 664.5, and at this pool creates a lift of 20.5 feet from the tailwater created by Pike Island Locks and Dam, at mile 84.2. The New Cumberland pool extends 22.7 miles upstream to Montgomery Locks and Dam. The dam is founded on rock varying from gray siltstone to gray and brown sandstone. The stilling basin is founded on steel H-piles and there is a steel sheetpile cutoff under the end sill. A plate girder service bridge spans the distance from the land wall pier to the abutment pier. The span over the landward lock chamber is a lift span designed to be raised 10.5 feet to provide a clear distance of 68 feet above normal upper pool.

Two parallel lock chambers are located along the right bank of the river. There is a 110-foot by 600-foot landward chamber and a 110-foot by 1200-foot riverward chamber. Each lock has two sets of hydraulically operated steel miter gates opening into recesses in the walls. Each lock wall has a filling and emptying culvert controlled by hydraulically operated reverse tainter valves. Each wall has a set of eight intake and eight discharge ports. The land chamber is filled and emptied through six laterals that extend form the land wall culvert across the land wall floor. The river chamber is filled and emptied by the middle and river wall culverts through ports located in the walls. The lock walls are concrete gravity walls founded on rock. The guard walls and guide walls are built on pile foundations of varying types.

The dam tainter gates are operated by bar-link type hoisting chains driven by a sprocket wheel and electric motor-driven hoist mechanism. Each sprocket is driven by a large gear reduction unit through a spur gear and pinion. The operating machinery for each of the lock miter gates consists of a sector arm and strut, sector gear, and rack in a single horizontal plane. A hydraulic cylinder actuates the rack. The operating machinery for each reverse tainter valve consists of a connecting rod, rocker, and strut oriented in a vertical plane. The connecting rod is attached to a piston rod and piston actuated by a hydraulic cylinder. Three constant delivery type hydraulic fluid pumps and one pressure holding pump located in the operations building on the middle wall power the hydraulic system. There are separate pipe systems for each lock with interconnection at the pumps. Other machinery includes a locomotive crane, traveling bulkhead hoist, lift-span hoisting machinery, emergency generator, and air compressor.

A set of four interchangeable truss-type emergency bulkheads, each nine feet high, are stacked to provide the required heights for closure of the dam gate bays or lock chambers. Units are raised, lowered, and transported by a traveling hoist equipped with a lifting beam. Poiree dams are used for downstream maintenance closure of the lock chambers

A recent aerial photograph is shown in Figure ED 4-16 and a site plan/vicinity map is shown in Figure ED 4-17 to give the reader a better feel of the project's characteristics.

Figure ED 4-16. Aerial View of the New Cumberland L&D Project

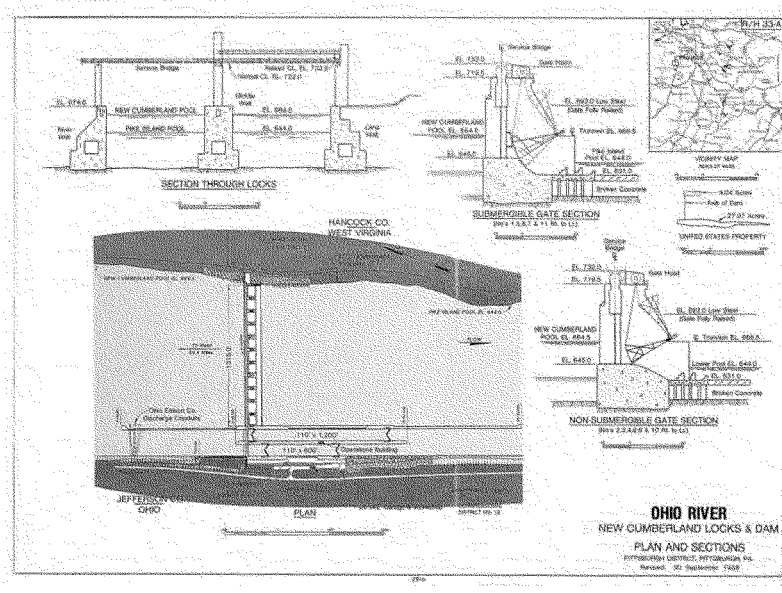

Figure ED 4-17. Plan View and Vicinity Map of the New Cumberland L&D Project

4.6.3 Assessment of Concerns and Needs – New Cumberland

Concerns with the lockwalls are related to cracking and relative movements. The river wall has an alignment problem. Some river wall monoliths have moved and/or rotated Survey monitoring pins have been installed on all river wall monoliths and are routinely being monitored by survey crews. Additional foundation drilling and testing needs to be performed to obtain actual strength parameters for purposes of reanalyzing lockwall stability. Cracking is a problem in the lockwall monoliths. This is true in all walls; however the middle wall appears most severe. Cracks have appeared in each monolith below the downstream auxiliary chamber miter gates. These cracks generally run longitudinally across the top surfaces of the monoliths, and extend downward to the galleries, and in some cases to the culvert. Crack surveys have been partially performed but need to be completed throughout all lockwalls and galleries. Exterior horizontal surfaces need to have cracks routed and sealed to prevent water intrusion and arrest crack growth, perpetuated from freeze-thaw cycles. Movement of the end monoliths on the guard walls (upper and lower bullnoses) have occurred such that the monolith joints have "opened" both vertically and horizontally. The most severe is the upper bullnose, exhibiting a horizontal opening of one inch down to the water line. Alignment pins have been installed and survey crews provide routine monitoring.

Concerns with the dam relate mostly to relative movements of piers and a significant crack in the abutment wingwall. Alignment pins have been installed along the top of the dam and are routinely monitored. Some pier movements have been recorded at 0.4". The upstream abutment wingwall contains a significant crack and is also being monitored.

Auxiliary chamber miter gates have heavy corrosion on many members and heavy leakage at the quoin and miter blocks. These gates are original and have been in service for approximately 45 years. Miter gates in the main 1200-ft chamber were replaced in 2002 due to the heavy damage to these miter gates through continued use and corrosion..

4.7 PIKE ISLAND LOCKS AND DAM

4.7.1 Project Information – Pike Island

Pike Island Locks and Dam is located on the Ohio River about 12 miles north of Wheeling, West Virginia, at river mile 84.2. The locks are located in Ohio County, West Virginia, and the abutment is in Belmont County, Ohio. It is the fifth navigation facility from the head of the Ohio River. Its upper pool extends 30 miles upstream to New Cumberland Locks and Dam.

4.7.2 Project Layout – Pike Island

The dam is a combination gated and fixed crest weir concrete structure with an overall length of 1,306 feet. The dam consists of eight intermediate piers, nine broad crested gated weirs, two end piers, and a fixed weir on the right abutment end. Flow is controlled by five submergible gates and four non-submergible gates, each 110-feet wide.

Normal upper pool elevation is 644.0 feet, 21 feet above the normal lower pool elevation of 623.0 feet, created by Hannibal Locks and Dam, downstream. The dam and the piers are founded on rock. The reinforced concrete stilling basin contains one row of baffles, and terminates at the end of the piers with a four-foot high end sill. The stilling basin apron is founded on steel bearing piles driven to rock with a concrete cutoff wall to rock at the downstream edge. A post-tensioned concrete box girder bridge extends across the dam and both lock chambers and carries a concrete deck, walkways, and a traveling hoist for placement of the bulkheads. An auxiliary crane for maintenance is carried on the hoist frame.

Two adjacent and parallel lock chambers are located on the left bank. The landward chamber is 110 feet by 600 feet and the riverward chamber is 110 feet by 1200 feet. The tops of the lock walls are at elevation 656.0. Each lock has two sets of hydraulically operated steel miter gates opening into recesses in the walls. Each lock wall contains a filling and emptying culvert through which flow is controlled by hydraulically operated reverse tainter valves. The land (600-foot) chamber is filled and emptied through six laterals extending across the floor from the land wall culvert. The river (1200-foot) chamber is filled and emptied by the middle and river wall culverts through ports located in the walls. The main lock walls are concrete gravity sections founded on rock. The upper guide wall is unreinforced concrete founded on steel bearing piles. Both the upper and lower guard walls are concrete caps over sheet pile cells enclosing steel bearing piles. The upstream emergency closures are steel bulkheads placed by a movable crane on an overhead bridge. Downstream closure is accomplished using poiree dams.

The dam tainter gates are operated by means of wire ropes and electric powered hoists. Each gate is operated by means of a drive-end unit and a driven-end unit, spaced and attached to the service bridge framing across the gate opening. The operating machinery for the lock miter gates consists of a sector arm and strut, sector gear, and rack in a single horizontal plane. The rack is connected to the piston rod of a hydraulically actuated cylinder. The operating machinery for each reverse tainter valve consists of a connecting rod, rocker and strut oriented in a vertical plane. The connecting rod is attached to the piston rod of a hydraulically actuated cylinder. The hydraulic system is powered by three constant delivery type service hydraulic oil pumps and one pressure holding oil pump located in the operation building on the middle wall. There are separate pipe systems for each lock with interconnection at the pumps. Other machinery includes a bulkhead hoist and crane with an auxiliary locomotive crane, emergency generator, air compressor, jib cranes, and an elevator.

A recent aerial photograph is shown of the Pike Island project is shown in Figure ED 4-18.

Figure ED 4-18. Aerial View of the Pike Island L&D Project

4.7.3 Assessment of Concerns and Needs – Pike Island

Concerns with the dam relate to heavy corrosion and deterioration of the service bridge crane rail and securing devices/fasteners. Corrosion is prevalent throughout but the most severe is approximately above the two gates at the center of the service bridge. These gates are operated most frequently, and a theory is that increased gate movements result in increased water spray across the top of the dam. Given freeze-thaw cycles, this wet environment has apparently led to extreme damage to the crane rails. Grout pads supporting the rails are heavily spalled and damaged. Further spalling could lead to loss in bearing support for the crane and hence a safety problem. One abutment wingwall has cracked and spalled and is also being monitored. Heavy corrosion of dam gates has been an ongoing problem at Pike Island. Several contracts have been awarded to procure painting/metalizing services. Two dam gates (No. 4 and 9) remain unpainted but are on the remedial measures list. Both of these gates are overflow or submersible gates and desperately require cleaning and painting. Seepage is occurring thru a lift joint in the fixed weir.

4.8 HANNIBAL LOCKS AND DAM

4.8.1 Project Information - Hannibal

Hannibal Locks and Dam is located on the Ohio River at river mile 126.4. The locks are in Monroe County, Ohio, and the abutment is in Wetzel County, West Virginia, at the town of New Martinsville. It is the sixth navigation facility from the head of the Ohio River. Its upper pool extends 42.2 miles upstream to Pike Island Locks and Dam.

4.8.2 Project Layout - Hannibal

The dam is 1067 feet long, from the river face of the river wall to the river face of the hydropower plant, with eight gated bays, each 110 feet long, and a fixed crest weir, 79 feet long. There are seven intermediate piers and two end piers. The fixed weir is located between the gated portion of the dam and the hydropower plant. Eight non-submersible fixed trunnion radial lift tainter gates control flow. Normal upper pool elevation is 623.0 feet, 21 feet above the normal lower pool of 602.0 feet, created by Willow Island Locks and Dam, downstream. The dam is founded on rock. The reinforced concrete stilling basin extends 41 feet downstream from the ends of the piers, contains one row of baffles, and terminates with a four-foot high end sill. A concrete girder service bridge spans from a pier on the land wall to the pier adjacent to the fixed weir. The span over the landward lock chamber is designed to provide a navigation clearance of 68 feet above normal pool.

Two side-by-side lock chambers are located along the right bank of the river. The landward chamber is 110 feet by 600 feet and the riverward chamber is 110 feet by 1200 feet. Each lock gate has two sets of hydraulically operated steel miter gates opening into recesses in the walls. Each lock wall contains a filling and emptying culvert through which flow is controlled by hydraulically operated reverse tainter valves. The land (600-foot) chamber is filled and emptied through nine laterals extending across the floor from the land wall culvert. The river (1200-foot) chamber is filled and emptied by the middle and river wall culverts through ports located in the walls. The main lock walls are concrete gravity walls founded on rock. The guard walls and guide walls are built on pile foundations of varying types.

The dam tainter gates are operated by means of wire ropes and electric powered hoists. Each gate is operated by means of a drive-end unit and a driven-end unit, spaced and attached to the service bridge framing across the gate opening. The operating machinery for the lock miter gates consists of a sector arm and strut, sector gear, and rack in a single horizontal plane. The rack is connected to the piston rod of a hydraulically actuated cylinder. The operating machinery for each reverse tainter valve consists of a connecting rod, rocker and strut oriented in a vertical plane. The connecting rod is attached to the piston rod of a hydraulically actuated cylinder. The hydraulic system is powered by three constant delivery type service hydraulic oil pumps and one pressure holding oil pump located in the operation building on the middle wall. There are separate pipe systems for each lock with interconnection at the pumps. Other machinery includes a bulkhead hoist, generator, air compressor, jib cranes, and an elevator.

A set of three interchangeable bulkhead units, each ten feet high, are stacked to provide the height needed as a bulkhead in the dam gate bays upstream of the tainter gates; as an overflow weir for passage of ice and debris from the upstream approach; as a maintenance or emergency bulkhead at the upstream end of a lock. The bulkhead units are raised, lowered, and transported by a traveling hoist equipped with a lifting beam.

Five bulkhead units, each six feet high, are used in conjunction with the emergency bulkheads in dewatering each tainter gate bay for inspection, repair, or maintenance purposes. These six-foot high bulkhead units are also used downstream of the lower miter gates for maintenance closures and upstream of the emergency dam sill for access to the in-place emergency bulkhead. The six-foot high bulkhead units are installed and removed by a floating crane.

More detailed information on the configuration of Hannibal Locks and Dam as well as selected as-built drawings can be found in Appendix X of the Hannibal Locks and Dam, First Periodic Inspection Report.

The New Martinsville Hydroelectric Project is located on the left bank of the Ohio River and is integral with Hannibal Dam, abutting the fixed crest overflow weir section of the dam. Provisions were made during design of the dam for add-on hydropower by including four permanent sheetpile cells adjacent to the fixed crest weir, with the idea that these cells could be easily removed for construction of a powerhouse. Two of these sheetpile cells were removed along with one of the three fixed crest monoliths. The license for the hydroelectric project was issued in June 1984 to the City of New Martinsville, West Virginia. Burgess and Niple, Limited, of Columbus, Ohio provided engineering services for the City of New Martinsville. The primary contractor was Bechtel International with Canonie Construction Company. Features of the project include: a 365-foot long, approximately 125-foot wide approach channel; a cast-in-place reinforced concrete powerhouse equipped with two identical 17.86 MW horizontal Kaplan pit bulb turbines; a 495-foot long tailrace channel varying in width from 115 to 165 feet; and a 138 KV, 3 phase transmission line between the switchyard and the Monongahela Power substation, located approximately 1500 feet east of the site. A recent aerial photograph is shown in Figure ED 4-19 to give the reader a better feel of the project's characteristics.

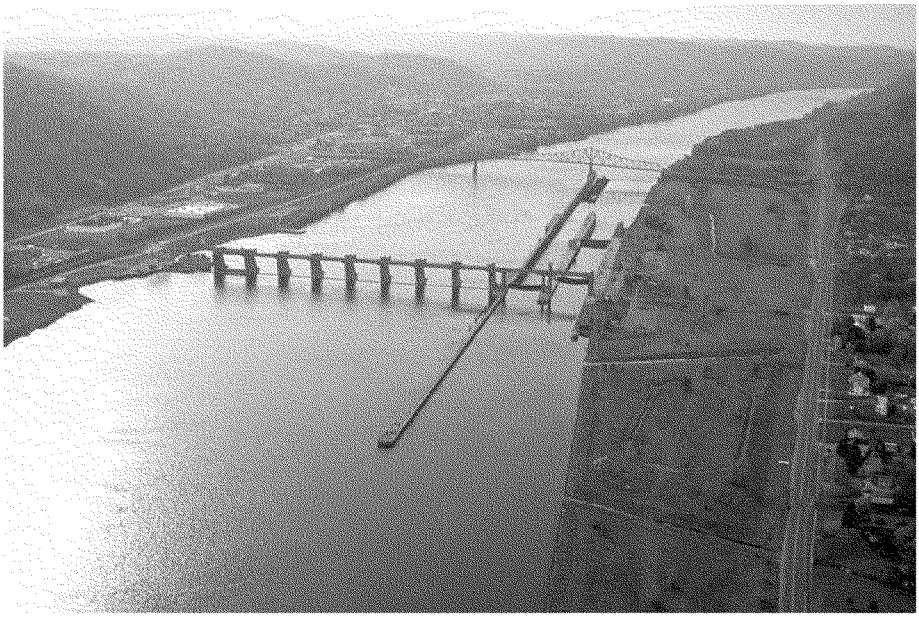

Figure ED 4-19. Aerial View of the Hannibal L&D Project

4.8.3 Assessment of Concerns and Needs - Hannibal

The Hannibal project was placed in operation in 1972 and is a modern lock and dam, generally in good condition with no significant problems.

One of the precast girders supporting the service bridge contains a crack on span No. 2, both upstream and downstream faces, and is regularly monitored during cyclic bridge safety inspections as well as by project personnel. Deterioration of expansion joint faces is prevalent along the bridge. Some joints are severe in that concrete chunks have broken off, causing concern that longitudinal expansion can freely take place without interference. Bridge bearings supporting the spans over the lock chambers have rotated to an angle which appears abnormal. This may be related to the thermal-induced superstructure expansion and contraction. Random tight cracks exist on the pier hammerheads. The fixed weir has a minor seepage problem across the top lift joint, adjacent to the hydropower plant.

Some operational issues require attention. The bulkhead latching devices use an air pressure latching system and often have problems latching, especially in winter months. The miter gates appear to have an alignment problem, possibly created by undo wear in the sector gear pin and bushings. The strut arms frequently require tightening. All gates in the 1200' chamber has a problem with the sector arms which have often rubbed the racks in the near open position. Clearances between the arms and the ribs on top of the racks may be the problem. The maintenance crane on the service bridge is functional; however, does not possess telescoping capability to make picks which creates difficulty for operators. Tainter gates are functional, structurally sound, and sealing satisfactorily; however, contain significant corrosion, mostly along the tailwater side along the splash zones.

4.9 WILLOW ISLAND LOCKS AND DAM

4.9.1 Project Information – Willow Island

Willow Island Locks and Dam (L&D) was authorized by the Secretary of the Army under the authority of Section 6 of the River and Harbor Act approved 3 March 1909, as a replacement for Ohio River Locks and Dams No. 15, 16, and 17. The lock construction contract was awarded in 1968 and navigation traffic began using the facility in 1972 during construction of the dam. Construction of the dam was completed in 1976. The pool was raised to full height in September 1975. It is under the jurisdiction of the Huntington District.

Willow Island L&D is located 161.7 river miles downstream of Pittsburgh, Pennsylvania. It is also 3.4 miles upstream of Waverly, West Virginia. The navigation locks are located on the North bank, or the Ohio side of the river. The pool extends from the dam upstream for a distance of 35.3 miles to Hannibal Dam, located at river mile 126.4. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-

1 to provide orientation with other Ohio River navigation pools relative to the Willow Island project.

4.9.2 Project Layout – Willow Island

The Willow Island project features two parallel lock chambers with a non-navigable, gated dam. The dam includes a 111' fixed weir with an 84' open crest. A recent aerial photograph is shown in Figure ED 4-20 and a site plan/vicinity map is shown in Figure ED 4-21 to give the reader a better feel of the project's characteristics.

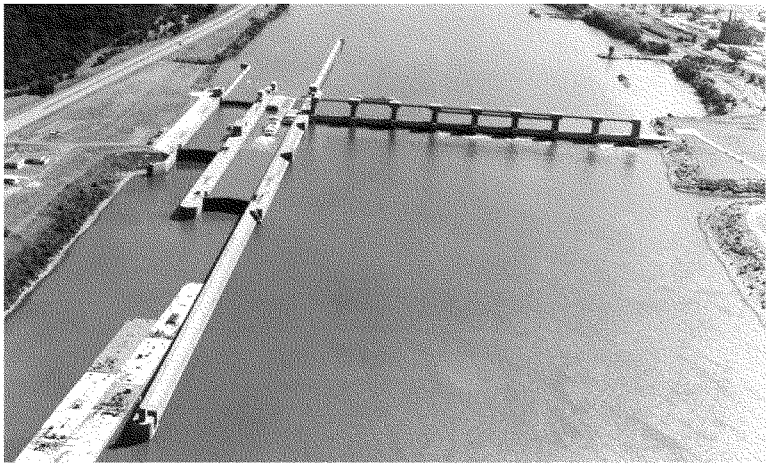

Figure ED 4-20. Aerial view of the Willow Island L&D Project

Two adjacent parallel locks are located on the Ohio bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The main lock is filled or emptied through longitudinal culverts in both walls; the auxiliary locks' culverts are in the land wall only. Flow is then distributed in the main lock using ports along the monoliths and in the auxiliary lock using a lateral system that extends from the culverts across the lock floor. Emergency gates are located immediately upstream of the upstream miter gates. These gates are vertical lift gates. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

The dam is a non-navigable, high-lift, gated dam, top length 1,128' including a 111' fixed weir with 84' open crest. It consists of 8 tainter gates with each gate having a clear span of 110' between piers, a damming height of 26' above the sills, and a clearance above the maximum high water level of approximately 5' when fully raised.

Normal upper pool is elevation 602.0 mean sea level and the normal upper pool surface area is 6,400 acres. Normal lower pool is elevation is 582.0 mean sea level. The lift at normal pool levels is 20'.

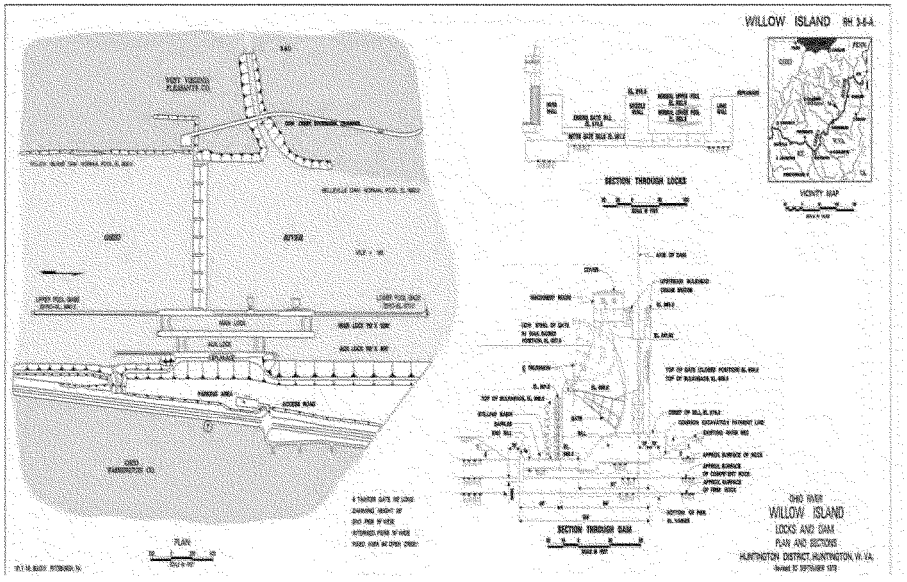

Figure ED 4-21. Plan View and Vicinity Map of the Willow Island L&D Project

4.9.3 Assessment of Concerns and Needs – Willow Island

There has not been any major deterioration or any significant deficiencies noted during recent inspections. This includes a dewatered inspection of the main chamber conducted in July 1999. The dewatered inspection did not include a thorough cleaning to remove all zebra mussels and debris prior to inspection. Therefore, as is discussed under the assessment of concerns and needs for Meldahl L&D, corrosion of the miter gate girder webs may not have been apparent although present.

Monoliths R-89 and R-90 (Upper Guard Wall) have moved causing an open joint between the two monoliths, mainly in the upper ¼ of the monoliths. Presently, this joint is being monitored through visual inspections and periodic diver inspections, but does not present a structural concern.

4.10 BELLEVILLE LOCKS AND DAM

4.10.1 Project Information - Belleville

Belleville Locks and Dam (L&D) was authorized by the Secretary of the Army under the authority of the River and Harbor Act approved 3 March 1909, as a replacement for Ohio River Locks and Dams Nos. 17, 18, 19, and 20, Dam No. 1 on the Little Kanawha River, and Dam No. 1 on the Muskingum River. Construction of the locks was initiated in June 1963 and they were placed in operation 12 October 1965. Construction of the dam was started in September 1964 and the pool was raised to full height 1 November 1968. It is under the jurisdiction of the Huntington District.

Belleville L&D is located 203.9 river miles downstream of Pittsburgh, Pennsylvania. It is also 0.5 miles downstream of Belleville, West Virginia. The navigation locks are located on the west bank, or the Ohio side. The pool extends from the dam upstream for a distance of 42.2 miles to Willow Island L&D, located at river mile 161.7. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation pools relative to the Belleville project.

4.10.2 Project Layout - Belleville

The Belleville project features two parallel lock chambers with a non-navigable, high-lift, gated dam. The dam includes a 189' fixed weir with a 130' open crest. A recent aerial photograph is shown in Figure ED 4-22 and a site plan/vicinity map is shown in Figure ED 4-23 to give the reader a better feel of the project's characteristics.

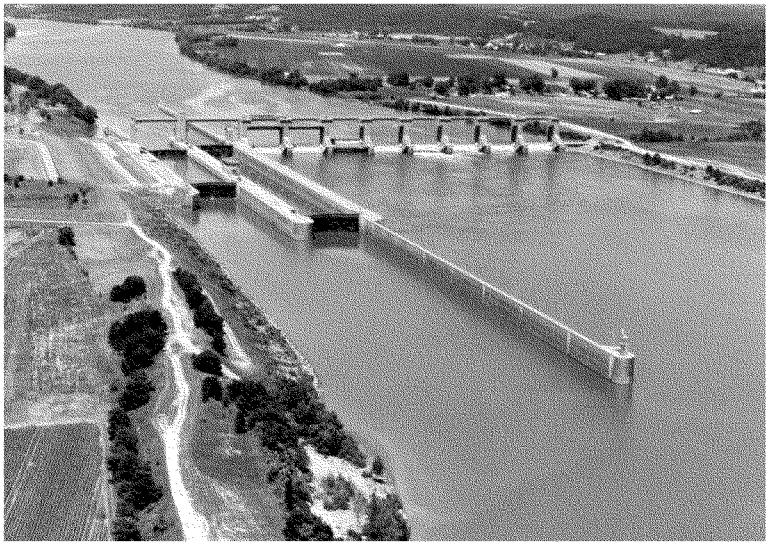

Figure ED 4-22. Aerial View of the Belleville Locks and Dam

Two adjacent parallel locks are located on the Ohio bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are

designed to fill and empty the locks in about eight minutes for each of these operations. The lock chambers are filled or emptied through a system of gated culverts in the interior of the lock walls and sets of transverse laterals along the floors of the lock chambers. Emergency closure is made by utilizing the dam gate bay emergency bulkheads which are placed immediately upstream of the miter gates in both the main and auxiliary locks. The bulkheads can be raised and lowered under flowing conditions using the bulkhead crane from the crane bridge which extends continuously over both locks and the dam. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

The dam is non-navigable, high lift, gated dam, top length 1,206' including a 189' fixed weir with a 130' open crest. It consists of 8 tainter gates with each gate having a clear span of 110' between piers, a damming height of 32' above the sills, and a clearance above the maximum high water level of approximately 5' when fully raised.

Normal upper pool is elevation 582.0 mean sea level and the normal upper pool surface area is 8,900 acres. Normal lower pool is elevation 560.0 mean sea level. The lift at normal pool levels is 22'.

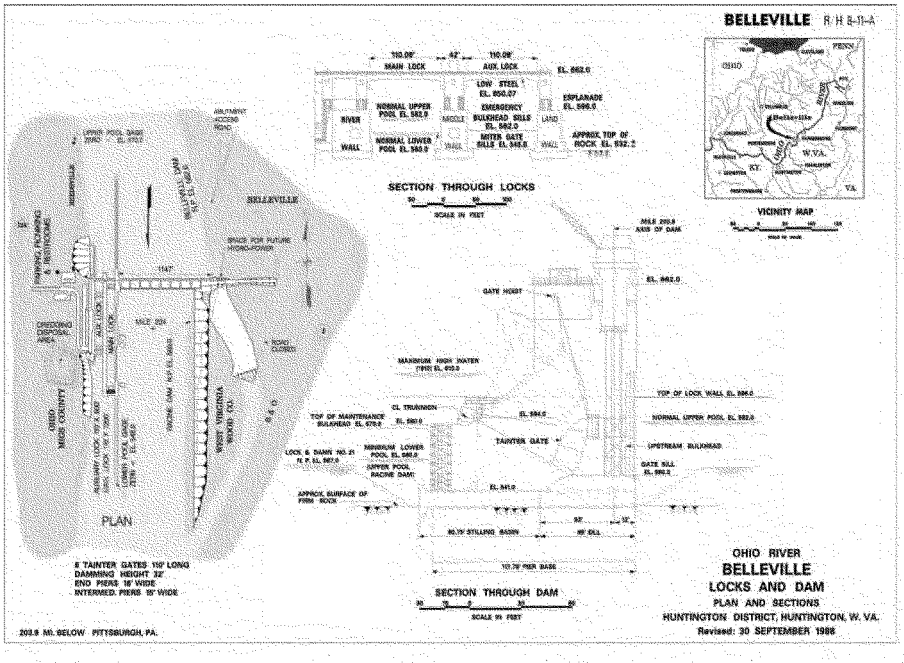

Figure ED 4-23. Plan View and Vicinity Map of the Belleville L&D Project

4.10.3 Assessment of Concerns and Needs - Belleville

There has not been any major deterioration or any significant deficiencies noted

during recent inspections. These inspections did not include a thorough cleaning to remove all debris from miter gates prior to inspection. Inspections identified minor spalling of concrete along lock walls, leakage around the miter gates, and minor leakage of miter gate machinery. None of these deficiencies present apparent structural or operational concerns.

4.11 RACINE LOCKS AND DAM

4.11.1 Project Information - Racine

Racine Locks and Dam (L&D) was authorized by the Secretary of the Army under the authority of the River and Harbor Act approved 3 March 1909, as a replacement for Ohio River Locks and Dams Nos. 21, 22, and 23. Construction of the locks was initiated in April 1965 and they were placed in operation 16 December 1967. Construction of the dam was started in August 1967 and the pool was raised to full height 24 August 1971. It is under the jurisdiction of the Huntington District.

Racine L&D is located 237.5 river miles downstream of Pittsburgh, Pennsylvania. It is also about 1.5 miles downstream of Letart Falls, Ohio. The navigation locks are located on the Northwest bank, or the West Virginia side. The pool extends from the dam upstream for a distance of 33.6 miles to Belleville Dam located at river mile 203.9. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation pools relative to the Racine project.

4.11.2 Project Layout - Racine

The Racine project features two parallel lock chambers with a non-navigable, high-lift, gated dam. Instead of the typical fixed weir adjacent to the dam, Racine has a hydroelectric plant operated by the American Electric Power Company. A recent aerial photograph is shown in Figure ED 4-24 and a site plan/vicinity map is shown in Figure ED 4-25 to give the reader a better feel of the project's characteristics.

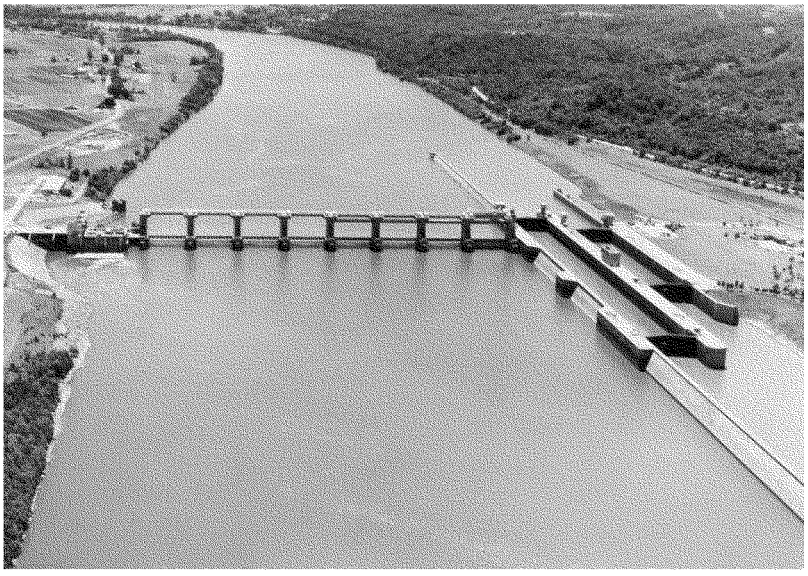

Figure ED 4-24. Aerial View of the Racine Locks and Dam

Two adjacent parallel locks are located on the West Virginia bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The main lock is filled or emptied through a system of gated culverts along the interior of the lock walls. These culverts are connected to sets of transverse laterals, with openings on the floor of the auxiliary lock chamber and port openings in the walls of the main lock chamber. Emergency closure of the locks is accomplished by two sets of vertical lift gates upstream of the upper miter gates. The downstream leaf of each emergency gate can be raised in flowing water. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

The dam is non-navigable, high lift, gated dam, top length 1,160' including the hydroelectric turbine building. It consists of 8 tainter gates with each gate having a clear span of 110' between piers, a damming height of 32' above the sills, and a clearance above the maximum high water level of approximately 5' when fully raised.

Normal upper pool is elevation 560.0 mean sea level and the normal upper pool surface area is 5,300 acres. Normal lower pool is elevation 538.0 mean sea level. The lift at normal pool levels is 22'.

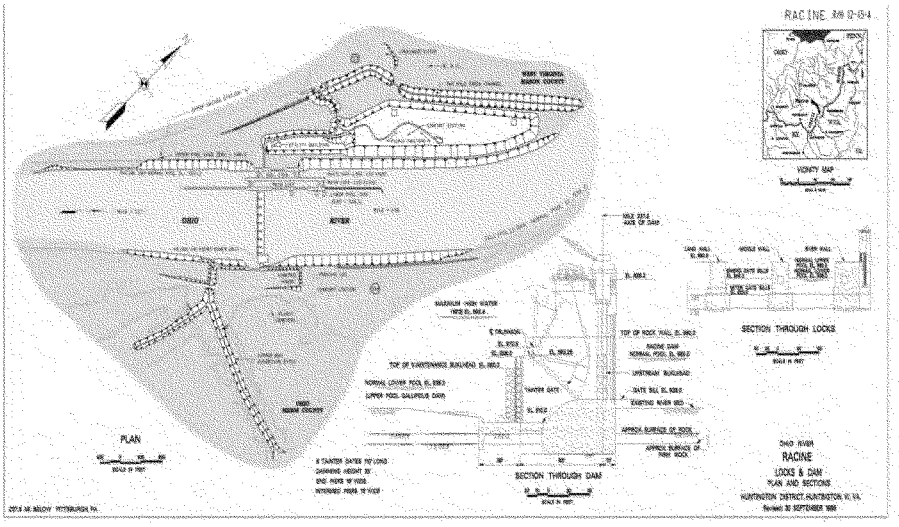

Figure ED 4-25. Plan View and Vicinity Map of the Racine L&D Project

4.11.3 Assessment of Concerns and Needs - Racine

There has not been any major deterioration or any significant deficiencies noted during recent inspections. These inspections did not include a thorough cleaning to remove all debris from miter gates prior to inspection. Inspections identified minor spalling of concrete along lock walls, significant leakage around the miter gates, and minor leakage of miter gate machinery. None of these deficiencies present apparent structural or operational concerns.

4.12 ROBERT C. BYRD LOCKS AND DAM

4.12.1 Project Information – Robert C. Byrd

Robert C. Byrd Locks and Dam was authorized by the Secretary of the Army under the authority of the River and Harbor Act approved 30 August 1935, as a replacement for Ohio River Locks and Dams Nos. 24, 25, and 26 on the Ohio River and Locks and Dams Nos. 9, 10, and 11 on the Kanawha River. The original Gallipolis locks were placed in operation on 25 August 1937. Construction of the dam was started in January 1935 and the dam was placed into operation in August 1937. Replacement of the original Gallipolis locks and rehabilitation of the original dam was authorized in the Supplemental Appropriation Act of 1985 and the Water Resources Development Act of 1986. Construction of the new Robert C. Byrd locks was started in October 1987 and completed in January 1993. It is under the jurisdiction of the Huntington District.

Robert C. Byrd L&D is located 279.2 river miles downstream of Pittsburgh, Pennsylvania. It is also 9.0 miles downstream of the City of Gallipolis, Ohio. The new navigation locks are located on the East bank, or the West Virginia side. The pool extends from the dam upstream for a distance of 41.7 miles to Racine Dam located at river mile 237.5 on the Ohio River and upstream for a distance of 44.6 miles to Winfield Dam located at river mile 31.1 on the Kanawha River. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation pools relative to the Robert C. Byrd project.

4.12.2 Project Layout - Robert C. Byrd

The Robert C. Byrd project features two parallel lock chambers with a non-navigable, high-lift, gated dam. A recent aerial photograph is shown in Figure ED 4-26 and a site plan/vicinity map is shown in Figure ED 4-27 to give the reader a better feel of the project's characteristics.

Two adjacent parallel locks are located on the West Virginia bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The main lock is filled or emptied through longitudinal culverts in both walls; the auxiliary locks' culverts are in the land wall only. Flow is then distributed in both locks using ports along the monoliths. Emergency gates are located immediately upstream of the upstream miter gates. These gates are vertical lift gates. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

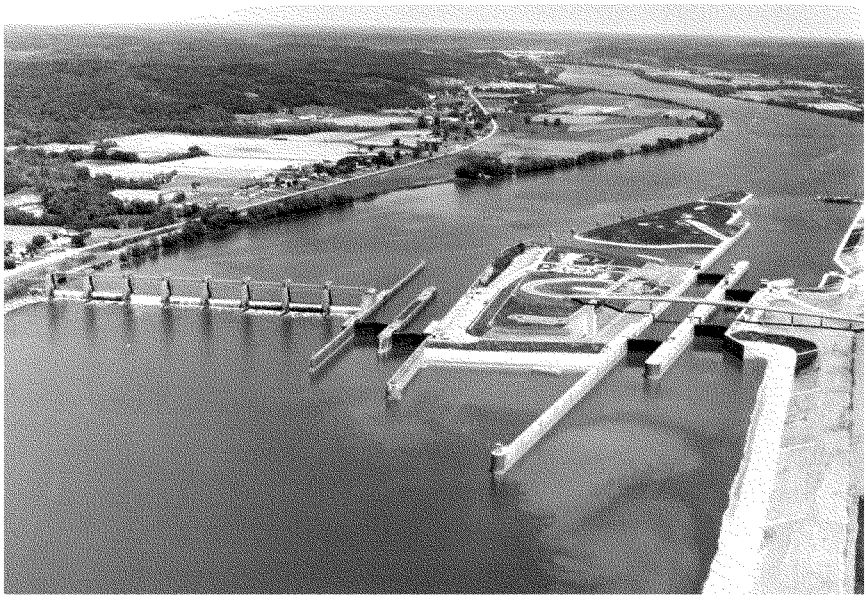

Figure ED 4-26. Aerial View of the Robert C. Byrd Locks and Dam

The dam is non-navigable, high lift, gated dam, top length 1,132'. It consists of 8 roller gates with each gate having a clear span of 125' 6" between piers and a damming height of 29' 6"' above the sills.

Normal upper pool is elevation 538.0 mean sea level and the normal upper pool surface area is 12,600 acres. Normal lower pool is elevation 515.0 mean sea level. The lift at normal pool levels is 23'.

4.12.3 Assessment of Concerns and Needs – Robert C. Byrd

There has not been any major deterioration or any significant deficiencies noted during recent inspections. The auxiliary chamber emergency gate failed in January 1994. One of the cables on the hoist equipment failed resulting in the gate becoming wedged in a partially raised position. The lower miter gates then had to be closed through the help of two 5600 horsepower tow boats supplied by the American Electric Power Company. After the lower miter gates were closed, the emergency gate was then lowered and the failed lifting cables were repaired. No other major issues noted.

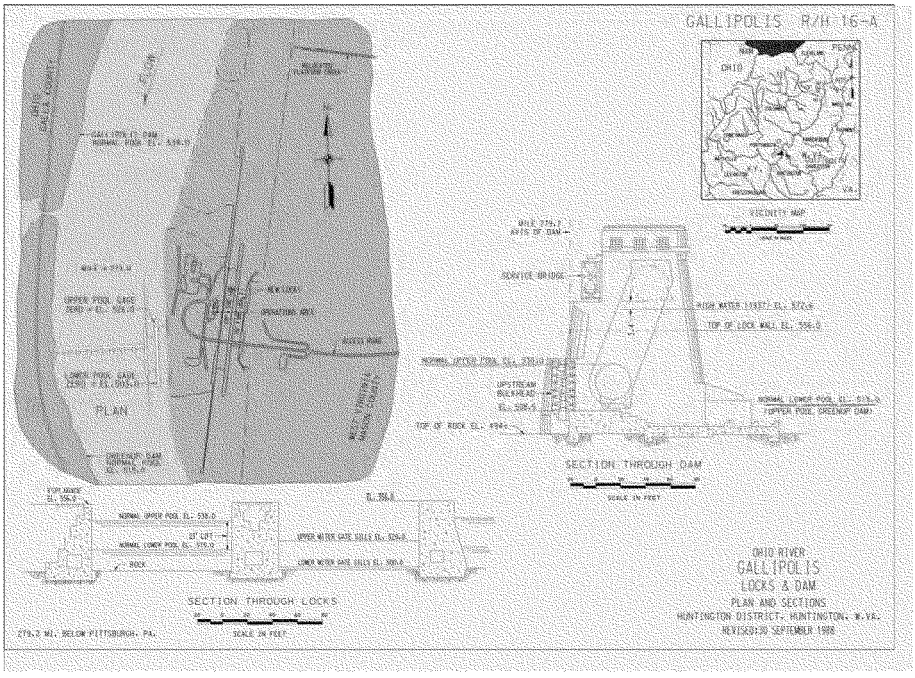

Figure ED 4-27. Plan View and Vicinity Map of the Robert C. Byrd L&D Project

4.13 GREENUP LOCKS AND DAM

4.13.1 Project Information - Greenup

Greenup Locks and Dam (L&D) was authorized by the Secretary of the Army under the authority of the River and Harbor Act approved 3 March 1909, as a replacement for Locks and Dams Nos. 27, 28, 29, and 30 on the Ohio River and Locks and Dam No. 1 on the Big Sandy River. Construction of the locks was initiated in October 1955 and they were placed in operation 27 November 1959. Construction of the dam was started in June 1958 and the pool was raised to full height 4 June 1962. It is under the jurisdiction of the Huntington District.

Greenup L&D is located 341.0 river miles downstream of Pittsburgh, Pennsylvania. It is also 5.0 miles downstream of Greenup, Kentucky. The navigation locks are located on the West bank, or the Kentucky side. The pool extends from the dam upstream for a distance of 61.8 miles to Robert C. Byrd Dam located at river mile 279.2. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation pools relative to the Greenup project.

4.13.2 Project Layout - Greenup

The Greenup project features two parallel lock chambers with a non-navigable, high-lift, gated dam. The dam includes a 245' fixed weir with a 223' open crest. In addition to the fixed weir adjacent to the dam, Greenup has a hydroelectric plant operated by the City of Vanceburg, Kentucky. A recent aerial photograph is shown in Figure ED 4-28 and a site plan/vicinity map is shown in Figure ED 4-29 to give the reader a better feel of the project's characteristics.

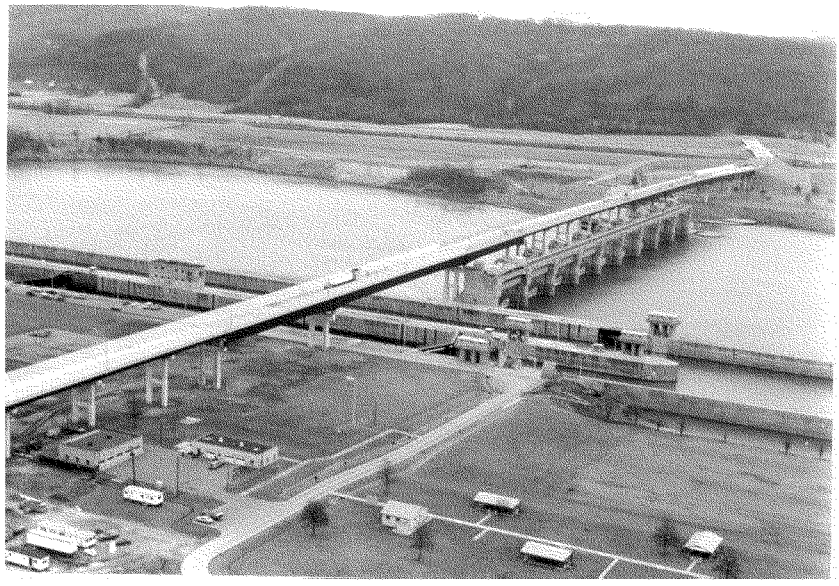

Figure ED 4-28. Aerial View of the Greenup Locks and Dam

Two adjacent parallel locks are located on the Kentucky bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The main lock is filled or emptied through a system of gated culverts located in the lock walls. These culverts are connected to sets of transverse laterals across the floor of the lock chambers. Emergency closure of the locks is accomplished by two sets of vertical lift gates upstream of the upper miter gates. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

The dam is non-navigable, high lift, gated dam, top length 1,287' including a 245' fixed weir with a 223' open crest. It consists of 9 tainter gates with each gate having a clear span of 100' between piers, a damming height of 35' above the sills, and a clearance above the maximum high water level of approximately 5' when fully raised. There are two types of gates within the dam, submergible and non-submergible ogee sill units.

Normal upper pool is elevation 515.0 mean sea level and the normal upper pool surface area is 11,200 acres. Normal lower pool is elevation 485.0 mean sea level. The lift at normal pool levels is 30'.

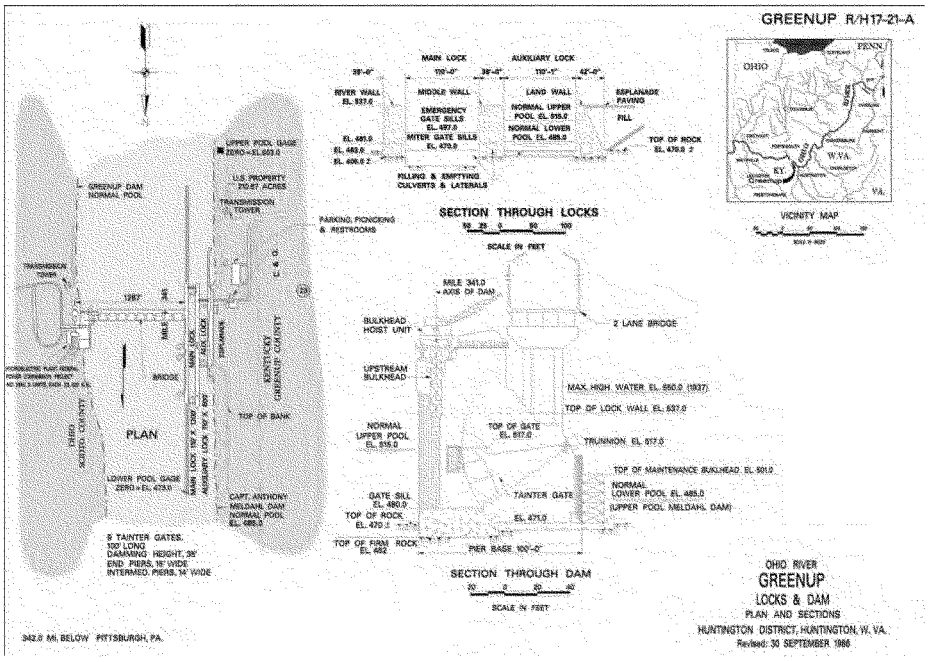

Figure ED 4-29. Plan View and Vicinity Map of the Greenup L&D Project

4.13.3 Assessment of Concerns and Needs - Greenup

There are a couple of major concerns associated with the Greenup Project. First, inadequate auxiliary lock chamber capacity is an issue that is being addressed through the Greenup Lock Extension Project, which was authorized as part of WRDA 2000. When completed, this project will have twin 1200-ft lock chambers which essentially eliminates the concerns regarding insufficient auxiliary chamber capacity. This is of primary importance when the existing main chamber is closed for maintenance, emergency, or other requirements. The Greenup Lock Extension Project was authorized as part of an interim report on the ORMSS and also included a capacity improvement project at J.T. Myers Locks and Dam in the Louisville District. Refer to the J.T. Myers section of this engineering appendix for more detail associated with that project. The capacity improvements at Greenup included extending the existing auxiliary chamber by a nominal 600 feet, providing a new supplemental filling and emptying system for the extended lock chamber, extensions to the existing approach walls, approach mooring cells for improved transit, and new gates/operating machinery for the extended auxiliary lock chamber. The Greenup Lock Extension Project is currently in design. The "on-line"

date for both Greenup and J.T. Myers capacity improvements was assumed to be 2010 at the time of the authorization.

Another major concern specific to Greenup is the condition of the miter gates in the existing main chamber. During 2003, an extended maintenance closure was required to make emergency repairs to the heavily cracked miter gates. While the repairs were extensive, they are essentially temporary since these gates have reached the end of the service life. As a part of the overall Greenup Lock Extension Project, a major rehabilitation of the existing main chamber is included to replace damaged components, most notably the miter gates.

4.14 MELDAHL LOCKS AND DAM

4.14.1 Project Information - Meldahl

Meldahl Locks and Dam (L&D) was authorized by the Secretary of the Army under the authority of the River and Harbor Act approved 3 March 1909, as a replacement for Ohio River Locks and Dams Nos. 31, 32, 33, and 34. Construction of the locks was initiated in March 1959 and they were placed in operation in November 1962. Construction of the dam was started in April 1961 and the pool was raised to full height 31 March 1965. It is under the jurisdiction of the Huntington District.

Meldahl L&D is located 436.2 river miles downstream of Pittsburgh, Pennsylvania. It is also 1.7 miles downstream of Chilo, Ohio. The navigation locks are located on the North bank, or the Ohio side. The pool extends from the dam upstream for a distance of 95.2 miles to the Greenup Dam, located at river mile 341.0. A profile of the navigational pools of the Ohio River is presented in Figure ED 4-1 to provide orientation with other Ohio River navigation pools relative to the Meldahl project.

4.14.2 Project Layout - Meldahl

The Meldahl project features two parallel lock chambers with a non-navigable, high-lift, gated dam. The dam includes a 372' fixed weir with a 310' open crest. A recent aerial photograph is shown in Figure ED 4-30 and a site plan/vicinity map is shown in Figure ED 4-31 to give the reader a better feel of the project's characteristics.

Two adjacent parallel locks are located on the Ohio bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock of 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The lock chambers are filled and emptied through a system of gated culverts in the interior of the lock walls. These culverts are connected to sets of transverse laterals, with openings on the floor of the lock chambers between the lock walls. Emergency closure of the locks is accomplished by sets of vertical lift gates upstream of the upper miter gates. The downstream leaf of each emergency gate can be raised in flowing water. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sills, lock wall monoliths, lock chamber monoliths, and miter gate monoliths.

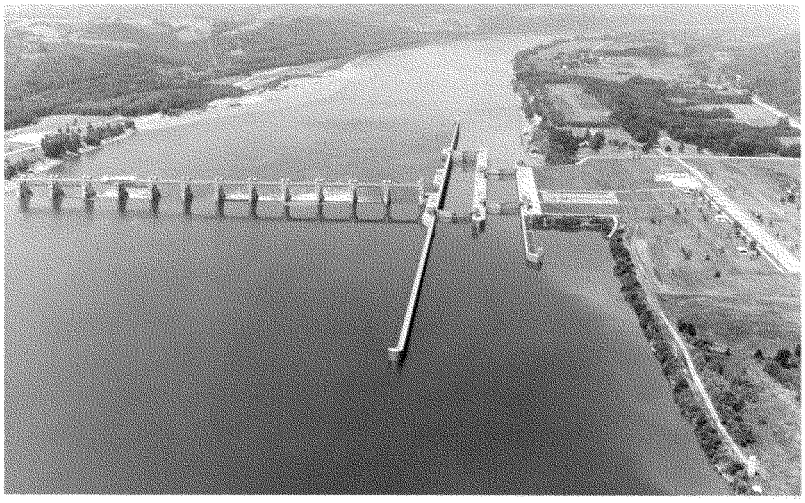

Figure ED 4-30. Aerial View of the Meldahl Locks and Dam

The dam is non-navigable, high lift, gated dam, top length 1,756' including a 372' fixed weir with a 310' open crest. It consists of 12 tainter gates with each gate having a clear span of 100' between piers, a damming height of 35' above the sills, and a clearance above the maximum high water level of approximately 5' when fully raised. There are two types of gates at the dam, submergible and non-submergible ogee sill units.

Normal upper pool is elevation 485.0 mean sea level and the normal upper pool surface area is 21,700 acres. Normal lower pool is elevation 455.0 mean sea level. The lift at normal pool levels is 30'.

4.14.3 Assessment of Concerns and Needs - Meldahl

Significant deterioration was noted during an inspection of the auxiliary lock chamber in 2002. The most extensive deterioration was noted on the lower girders of the downstream miter gate (G-10 and G-11) and included corrosion that had reduced members from an original thickness of 7/16" down to a thickness range of 0" (complete voids in girder web material) to 1/8" in several locations (see Figure ED 4-32). The cause of the accelerated deterioration in these locations was corrosion from excessive debris build-up inside the girder webs (see Figure ED 4-33). The Huntington District Maintenance Repair Fleet conducted emergency repairs to prevent further deterioration and catastrophic failure of the miter gate. These emergency repairs are only a temporary fix for the problem. There are no spare miter gates for this project and design and fabrication of new gates could take up to 18-24 months.

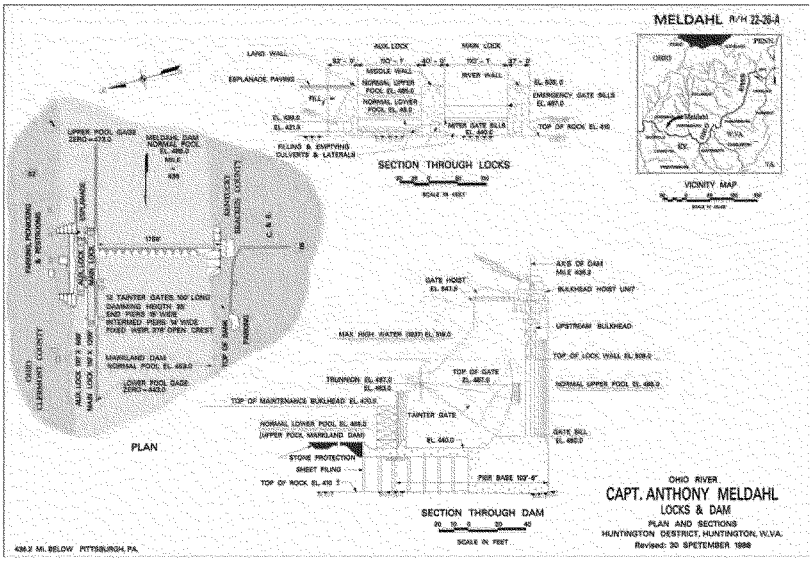

Figure ED 4-31. Plan View and Vicinity Map of the Meldahl L&D Project

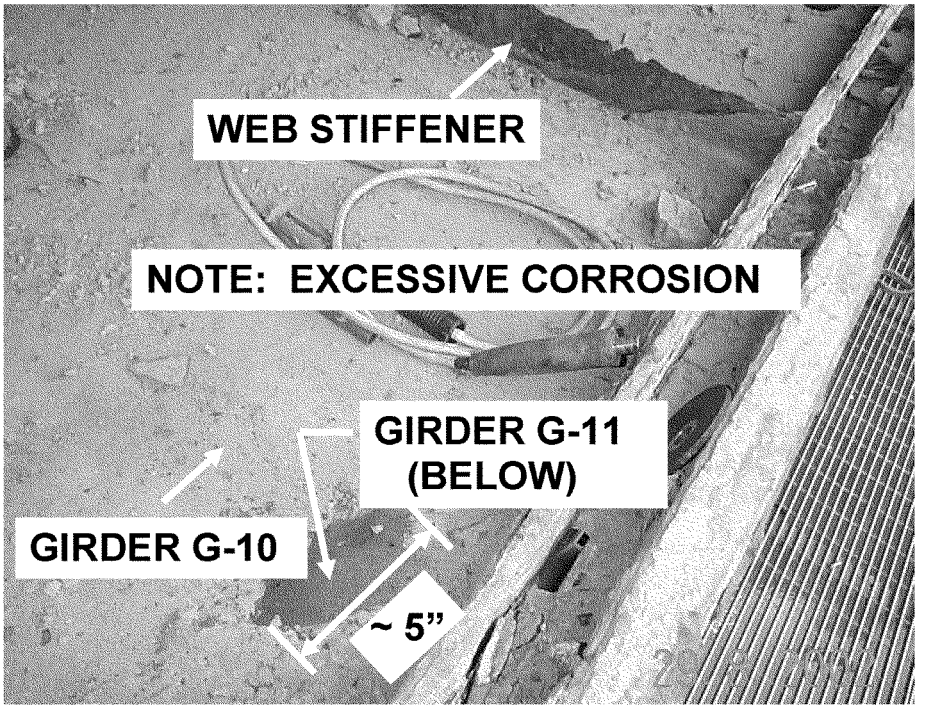

Figure ED 4-32. Corrosion Damage of the Downstream Aux. Miter Gate

This accelerated corrosion due to debris build-up is also a significant possibility on other Ohio River locks and dams that may not be identified during Periodic Inspections. During the initial inspection conducted at Meldahl after dewatering the auxiliary chamber in August 2003, no significant deterioration of any of the miter gates was noted. This inspection was conducted prior to the gates being thoroughly cleaned and then sand-blasted in apparent trouble locations. Following the thorough cleaning, the corrosion noted above was discovered. This would indicate that unless thorough cleaning is done prior to inspections on other projects, this same corrosion may go unidentified. Additionally, added Operations and Maintenance resources would enhance preventive maintenance by conducting a thorough cleaning annually thus possibly reducing corrosion.

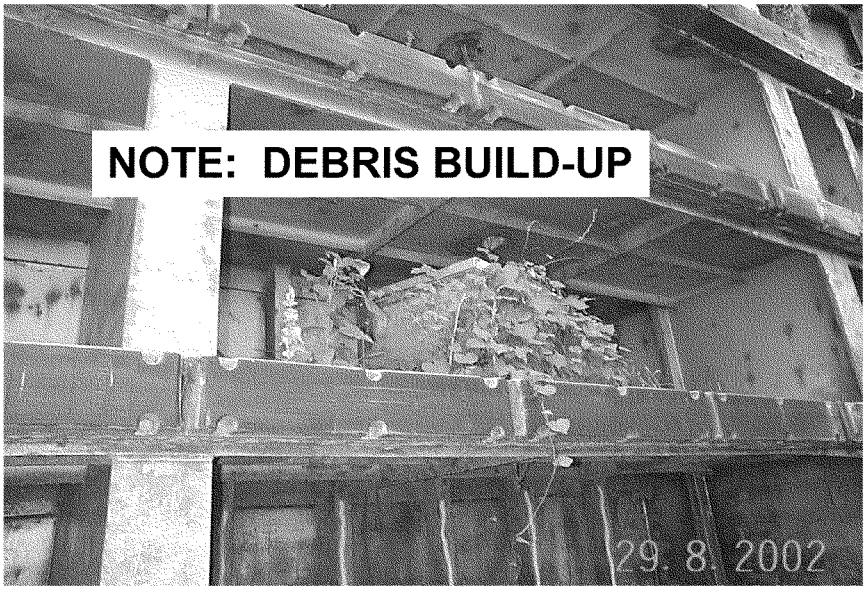

Figure ED 4-33. Excess Debris on Downstream Auxiliary Miter Gate

4.15 MARKLAND LOCKS AND DAM

4.15.1 General Background Information - Markland

Markland Locks and Dam (L&D) was authorized by the Secretary of the Army on 11 March 1953 under the authority of Section 6 of the River and Harbor Act approved 3 March 1909, as replacement for Ohio River Locks and Dams No. 35, 36, 37, 38 and 39. Construction of the locks was completed in 1956 with lockage beginning in 1958 during construction of the dam. Construction of the dam was completed in 1964. It is under the jurisdiction of the Louisville District. Markland L&D is located 531.5 river miles downstream of Pittsburgh, Pennsylvania, which is also 26.5 miles upstream of Madison, Indiana and 3.5 miles downstream of Warsaw, Kentucky. The navigation locks are located on the left bank, or the Kentucky side, of the river. The pool extends from the dam upstream for a distance of 95.3 miles to the Captain Anthony Meldahl L&D, river mile 436.0. The port of Cincinnati lies within Markland's pool, which extends short distances on three navigable tributaries – the Great Miami, Little Miami and Licking Rivers and borders portions of Kentucky, Indiana and Ohio. A profile of the navigational pools of the Ohio River is presented in Figure 4-1 to provide orientation with other Ohio River navigation Pools relative to the Markland project. Markland is a post-World War II lock which replaced the low-lift Ohio River Locks and Dams No. 35,36,37,38 and 39.

4.15.2 Project Layout - Markland

The Markland project features two lock chambers with a non-navigable, gated dam. Instead of the typical fixed weir adjacent to the dam, Markland has a small hydroelectric plant operated by an independent entity. A recent aerial photograph is shown in Figure ED 4-34 and a site plan/vicinity map is shown in Figure ED 4-35. A basic description of each main feature is provided below.

Two adjacent parallel locks are located on the Kentucky bank, the main lock chamber has clear dimensions of 110' x 1,200' and the auxiliary lock 110' x 600'. The main lock is located riverward of the auxiliary lock. Filling and emptying systems are designed to fill and empty the locks in about eight minutes for each of these operations. The main lock is filled or emptied through longitudinal culverts in both walls; the auxiliary lock's culverts are in the land wall only. A lateral system in the lock chambers extends from the culverts across the lock floors to distribute flows and reduce turbulence. Emergency gates are located immediately upstream of the upper miter gates of each chamber. These are double-leafed submergible gates that are electrically operated. An esplanade is along the landward lock. Other primary components of the locks are the miter gates, culvert valves, electrical system, mechanical system, miter gate sill, lock wall monolith, lock chamber monolith, and miter gate monolith.

Figure ED 4-34. Aerial Photograph of Markland Locks and Dam

The dam is non-navigable gated-crest structure, 1,395 feet long. It consists of a low concrete weir with 12 tainter gates supported by concrete piers. Each gate is 100' long and 42' high, with an operating radius of 64'. In 1977, the five submergible gates were converted to non-submergible, making all 12 gates non-submergible. Normal upper

pool is elevation 455.0 mean sea level. Normal lower pool is elevation 420.0 mean sea level. Thus, the lift is 35 feet at normal pool levels.

A bridge crossing the Ohio River, utilizing the Markland Dam as its foundation, was completed in August 1978. The bridge connects Indiana State Highway 156 in Switzerland County, Indiana and U.S. Highway 42 in Gallatin County, Kentucky. The nearest other bridges which cross the Ohio River are the I-275 and U.S. 421 bridges, about 40 river miles upstream and about 26 river miles downstream, respectively.

The Public Service Company of Indiana, under license granted by the Federal Power Commission, completed construction of a "run-of-river" hydroelectric power plant at Markland L&D. Capacity of the plant is 81,000 kilovolt-amperes (kva)

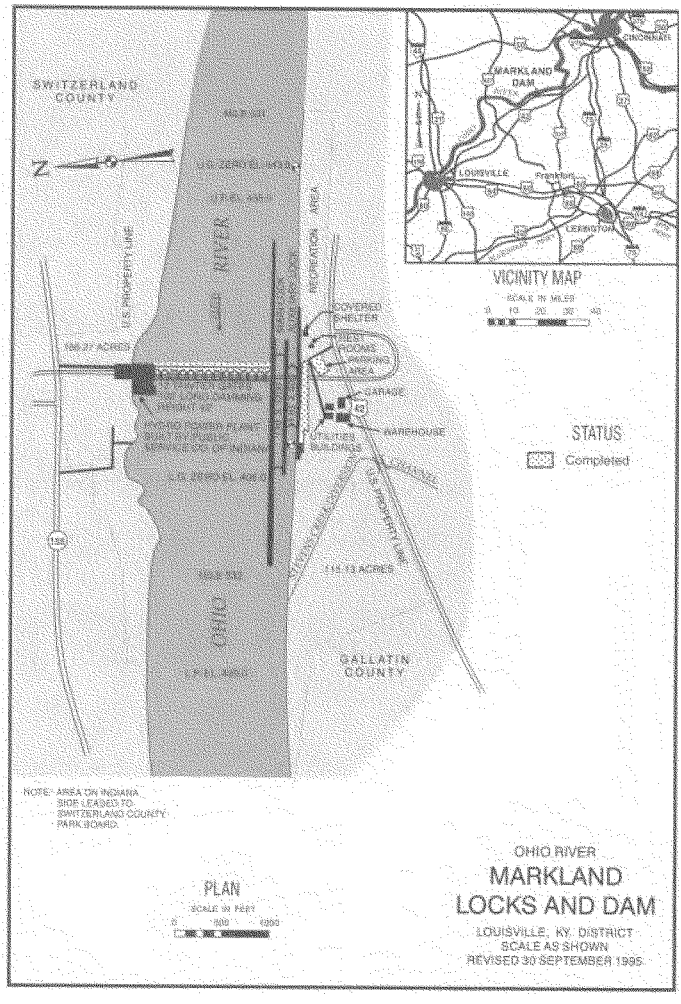

Figure ED 4-35. Project Layout of Markland Locks and Dam

4.15.3 Assessment of Concerns and Needs - Markland

Current traffic levels are near the capacity of the auxiliary chamber, which caused major delays to occur when the main chamber is closed. Unlike locks on other rivers, Ohio River locks operate throughout the entire year. The amount of traffic, and the level of service Markland L&D is called upon to provide to the towing industry, is evenly distributed throughout the year.

The major problem at Markland is the potential loss of service of the main lock due to the deteriorated condition of the existing miter gates and reverse tainter culvert valves and the subsequent impact to Ohio River Navigation. Emergency repairs to cracking and buckling of the main lock miter gates have been made several times since major fatigue damage was found during a routing 1994 maintenance dewatering. However, emergency repairs of the miter gates are only a temporary fix for the problem. Inspections following these prove that propagation of the fatigue cracking of the gates continues an increasing rate. This is also anticipated to occur on the welded reverse tainter culvert valves in the near future due to similar original construction technique and a high number of fatigue cycles. Typically, the main chambers of Louisville District locks on the Ohio River are dewatered every 5 years as part of on-going maintenance. However, the main chamber at Markland is now dewatered *every year* due to the deteriorated condition of the miter gates.

As a result of the deteriorated condition of the miter gates and limited funding through O/M sources, a Major Rehabilitation Evaluation of the Markland Project was undertaken in the late 1990's as a potential means to acquire new miter gates and culvert valves. The recommended plan resulting from this evaluation includes replacement of the main lock miter gates and culvert valves at the earliest possible time. This evaluation analyzed the existing and expected future reliability of the main auxiliary lock mite gates and several other essential lock components. The first cost of the recommended plan is $17.6 million, in Fiscal Year 2000 price levels. Annual costs of the recommended plan are almost $1.7 million and annual benefits are $4.3 million, giving a benefit-to-cost ratio of 2.6 and net benefits of $2.6 million. The Major Rehabilitation Report was approved at HQUSACE level in summer of 2000. However budget constraints have kept the Louisville District from receiving the necessary funds to replace the miter gates and culvert valves. Due to the inability to secure funds through Congress, the Louisville District is seriously concerned about the potential for a catastrophic failure of the miter gates and thus, has gone to dewatering the Markland main chamber every year until the miter gates and culvert valves can be replaced. This inability to secure funds is costing both USACE and the navigation industry millions of dollars due to the low reliability of these structures.

4.16 McALPINE LOCKS AND DAM

4.16.1 General Background Information - McAlpine

The McAlpine Locks and Dam project is located on the Ohio River at Mile 604.5 below Pittsburgh, Pennsylvania, at Louisville, Kentucky. The navigation locks are located on the left bank or Kentucky side of the river at Mile 606.8 and the upper pool

extends approximately 75 miles to the Markland Locks and Dam. The Secretary of the Army approved the project on November 8, 1955, under authority of Section 6 of the Rivers and Harbors Act approved March 3, 1909. It is under the jurisdiction of the Louisville. Refer to Figure ED 4-1 to see where the McAlpine project is located relative to other Ohio River navigation projects.

The Falls of the Ohio at Louisville consists of a rock reef, which extends across the river and forms rapids about 3 miles long. Prior to canalization, the Ohio River dropped 26 feet through the falls and navigation was impossible except at high water stages. The first navigation improvement was a 1.9 mile long canal and a three-flight lock built by a private stock company, which opened on 22 December 1830. By 1854, the United States had acquired practically all stock in the company and from 1868 to 1872, carried out a project of widening the 64-foot canal and replacing the 50-foot wide lock with a lager two-flight lock. In June 1874, the Corps of Engineers assumed supervision of navigation in the canal and in 1909, a movable weir dam was built to provide a minimum channel depth of 9 feet form Louisville to Madison, Indiana. Further improvements were made from 1911 to 1930 with the existing 110' x 600' lock completed ion 1921. The old two-flight lock was replaced in 1930 by a single lift 56' x 360' lock. Between 1925 and 1927, a movable weir dam with a navigable pass was built in conjunction with a hydroelectric power project of the Louisville Gas and Electric Company. This dam provided a 9-foot minimum channel depth from Louisville to Markland, Kentucky. Construction of the existing 110' x 1,200' main lock and the widening of the canal from 200' to 500' were completed in 1961. A major portion of the dam, the non-navigable fixed weir, and gate-controlled structures were constructed from 1961 to 1964. Reconstruction of the 600- foot intermediate lock and the 360-foot auxiliary lock was accomplished from 1963 to 1965.

The McAlpine replacement project was authorized by the water resources development act of 1990 to replace the dilapidated 360' and 600' lock chambers with a new 1200' lock chamber. Construction of the temporary cofferdam and demolition of the existing smaller lock chambers (360' and 600') began in the year 2000. Prior to these construction activities, the 600' chamber was only used as an emergency backup to the existing main chamber due to its poor condition. Figure ED 4-36 depicts the project at the start of the cofferdam construction process. Figure ED 4-37 shows an artists rendering of the completed project that is currently scheduled for completion in 2007.

4.16.2 Project Layout - McAlpine

The project is a high lift, gate controlled structure with and upper and lower gated site separated by a 1-1/2 mile long upstream-downstream concrete fixed weir along the upper edge of the former "Falls of the Ohio;" three adjacent parallel navigational locks located at the lower end of the Louisville and Portland Canal; a hydroelectric power plant located between the right downstream end of Shippingport Island and the lower gated structure and Shippingport Island itself. A site plan/vicinity map is shown in Figure ED 4-38 and a basic description of each main feature is provided below.

The dam consists of two non-navigational gated-crest type structures separated by a concrete fixed weir extending longitudinally with the river for about 1-1/2 miles. The lower gated section and powerhouse are separated from the locks by high ground (Shippingport Island), which forms a surge basin for the lock approach canal. The lower

Figure ED 4-36. Aerial Photograph of McAlpine Locks Prior to Replacement Project

gated section is separated form the powerhouse by a 70-foot section of concrete fixed weir and consists of four 100 feet long by 22 feet high tainter gates supported by concrete piers. These gates were originally of the submergible type but have been changed to the non-submergible type by converting the sills to ogee sections. The total length of the lower gated site is about 450 feet. The powerhouse is owned and operated by the Louisville Gas and Electric Company. The concrete fixed weir section between the lower and upper-gated structures is about 6,630 feet in length. It consists of fixed weir and pier sections, with the crest rising from elevation 422 at the lower end to elevation 423 at the cross-river leg or upper end. The upper-gated section consists of five non-submergible tainter gates 110 feet long by 22 feet high supported by concrete piers. The total length of the upper-gated site is about 560 feet. The concrete fixed weir section to the right of the upper-gated structure extends some 980 feet to the right-bank or Indiana side of the river. Each gated section with its tainter gates is of sufficient height to permit the raising of each gate 5 feet above maximum high water. These sections also have gate sills, a

crane bridge, and individual hoisting equipment for each gate. A set of three upstream bulkhead sections, sufficient for closing off one gate bay, is provided for each gated section.

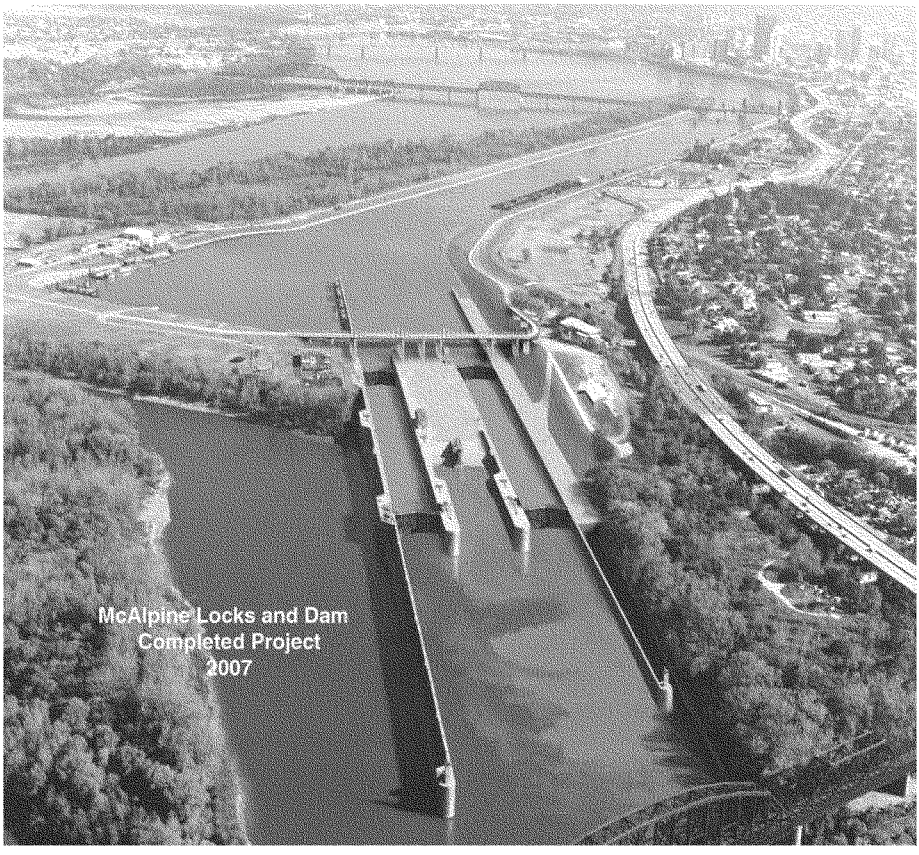

Figure ED 4-37. Artist's Rendering of Completed McAlpine Lock Replacement

The lock chambers, and existing 110' x 1,200' chamber and new 110' x 1,200' chamber under construction, are located along the Kentucky shore on the left side of the river. The new 110' x 1,200' lock chamber is replacing an inoperable 56' x 360' and deteriorated 110' x 600' lock chamber. After completion, the project will have twin 110' x 1,200' locks with a large esplanade between the lock chambers, as shown in Figure ED 4-5. A set of hydraulically operated steel miter gates is provided for each lock. The filling and emptying system of the main lock fills or empties the lock in about 8 minutes. The existing main lock emergency gate is located immediately upstream form the upper miter gates and consists of a double-leaf vertical submergible gate, electrically operated. Provisions are also provided for maintenance bulkheads immediately downstream of each set of miter gates. Eight aluminum truss maintenance bulkheads are available throughout

the Louisville District. By use of these bulkheads, each of the culvert valves, miter gates, and the entire lock chamber are designed for dewatering to facilitate maintenance.

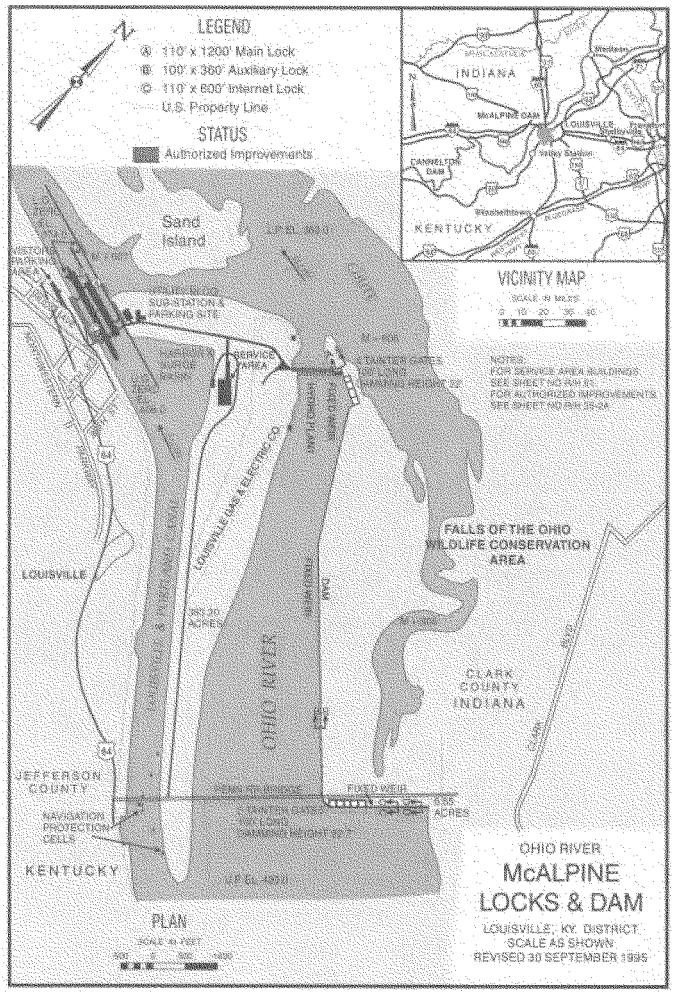

Figure ED 4-38. McAlpine Project Layout (Prior to Lock Replacement)

The Louisville and Portland Canal has a length of 2-1/7 miles including the locks and lower entrance. The width of the canal is 500 feet to the head of the locks where it widens to approximately 700 feet to include the harbor, etc. The minimum depth of the canal is 15 feet at normal pool. At the entrance to the canal are navigation protection cells upstream and downstream of the Pennsylvania Railroad Bridge with a horizontal clearance of 241.5 feet under the bridge.

Normal upper pool is at elevation 420.5 mean sea level. Normal lower pool (Cannelton Pool) is elevation 383.0 mean sea level. The lift is 37 feet at normal pool levels, which is the highest of all projects on the Ohio River.

The hydroelectric plant, owned and operated by the Louisville Gas and Electric Company, is located near the downstream end of the existing dam. The dam, together with the natural fall of some 26 feet in the riverbed at the falls, provides a maximum operating head of about 37 feet. At present, eight 13,500 horsepower units are installed with a total rated capacity of 80,320 kilowatts.

4.16.3 Assessment of Concerns And Needs - McAlpine

The McAlpine replacement project, when completed in 2007, takes care of the most critical needs of the overall project. As a part of the McAlpine replacement project a new set of miter gates, termed stand-by-gates, have been included in the event the deteriorated existing 1,200-ft chamber miter gates fail during construction of the new lock chamber, which would cause a total river shutdown. The stand-by miter gates will replace the existing 1,200' miter gates after the new chamber is operation if they are not needed during current construction. Beyond the lock replacement and replacement of the existing 1,200' chamber miter gates, the only foreseeable need will be to maintain the operating components of both 1,200' chambers. This may require individual component replacements for full-scale rehabilitation, particularly the existing 1,200' chamber that is already over 40 years old and has seen a high number of operating cycles.

4.17 CANNELTON LOCKS AND DAM

4.17.1 General Background Information - Cannelton

The Cannelton Locks and Dam project is located on the Ohio River at Mile 720.7 below Pittsburgh, Pennsylvania, 3 miles upstream from Cannelton, Indiana. The upper pool maintained above the dam extends upstream for a distance of 114 miles to the McAlpine Locks and Dam at mile 607 and for a short distance up Salt River. The navigation locks are located on the right descending bank or Indiana side of the river. It is under the jurisdiction of the Louisville District.

The project was approved as replacement of existing Locks and Dam 43, 44, and 45 on January 27, 1960, by the Secretary of Army under authority of Section 6 of the Rivers and Harbors Act approved March 3, 1909, as amended. Construction of the Cannelton Locks was started in July 1963; they were placed in operation December 1966 and completed April 1967. Up bound traffic started passing thorough the locks on 10 December 1966, while locking in both direction started in June 1970. Construction of the Cannelton Dam was started in August 1965 and was completed in 1974. As work progressed on the dam, the old outmoded upstream Locks and Dam Nos. 43, 44 and 45 were demolished and the pool progressively rose until maximum pool stage was reached. The Overlook property, consisting of 128 acres, was initially built during construction of the project. The property was excessed in 1995 to the US Fish and Wildlife to use as a wildlife habitat.

4.17.2 Project Layout - Cannelton

The project is a high lift dam with two adjacent parallel. A recent aerial photograph is shown in Figure ED 4-39 with the main lock chamber dewatered for maintenance. A site plan/vicinity map for Cannelton is shown in Figure ED 4-40. A basic description of each main project feature is provided below.

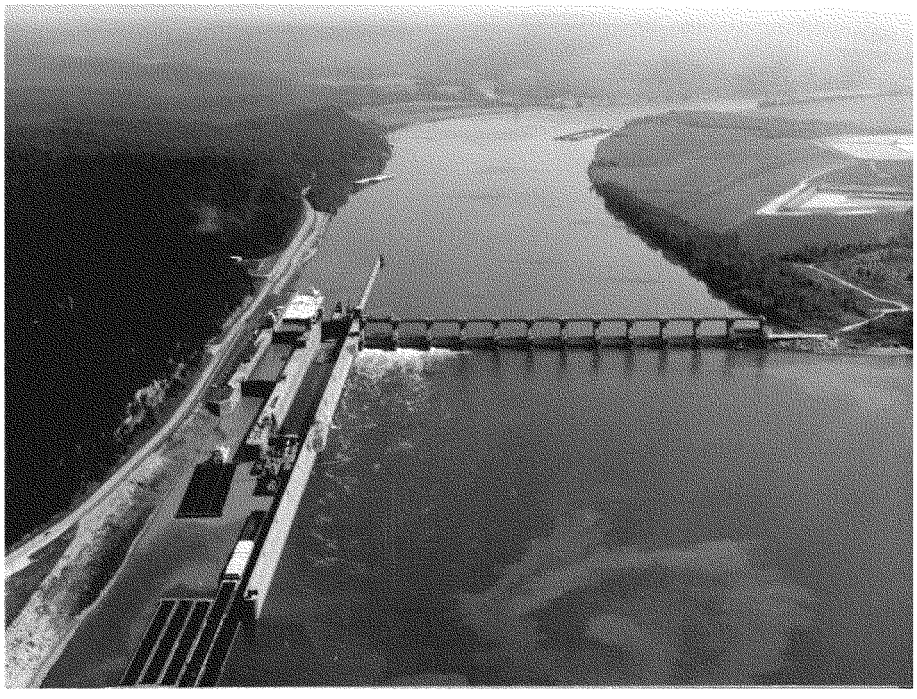

Figure ED 4-39. Aerial Photograph of Cannelton Locks and Dam

The dam consists of a non-navigable gated-crest type structure 1,395 feet long, a fixed weir section 213 feet long, and a concrete-capped sheet pile cutoff wall and dike 482 feet long terminating in natural ground on the left bank or Kentucky side of the river. There are 12 non-submergible tainter gates 100 feet long by 42 feet high supported by concrete piers. The fixed weir section is composed of concrete-capped sheet pile cells. The concrete-capped sheet pile cutoff wall extends from the end of the weir section further into the bank. The gated section of the dam is topped with a prestressed concrete service bridge and includes a crane for lifting the upstream emergency bulkheads. The two adjacent parallel lock chambers are located along the Indiana shore, the main lock chamber having clear dimensions of 110' x 1,200' and the auxiliary lock 110' x 600', with a 25-foot lift within the locks at normal pool. Two sets of hydraulically operated steel miter gates are provided for each lock. Emergency gates are located immediately upstream of the upper miter gates and are double-leaf vertical submergible electrically operated gates. Provisions for maintenance bulkheads are also provided immediately downstream of each set of miter gates. Sixteen aluminum truss maintenance bulkheads

are available throughout the Louisville District. By the use of bulkheads, each of the culvert valves, the miter gates and the entire lock chambers are designed for dewatering to facilitate maintenance. Normal upper pool is at elevation 383.0. Normal lower pool (Newburgh Pool) is elevation 358. Thus, the lift is 25 feet at normal pool levels.

4.17.3 Assessment of Concerns and Needs - Cannelton

There are several concerns and needs associated with the Cannelton project. The auxiliary chamber capacity relative to current and projected traffic levels, coupled with reduced reliability in future years, is one of the primary concerns associated with the Cannelton project. The economic issues relative to this situation is described in brief in Section 4.2 of this Engineering Appendix. The structural features of the projects are approaching 40 years of age. In addition, this project has historically been one of the higher use projects on the Ohio River due to its location on the lower river. Therefore, the long-term performance of major components such as miter gates, culvert valves, and operating machinery are of significant concern, particularly on the main chamber where historical and future projected cycles are considerable higher than the smaller, auxiliary lock chamber. In addition, many of the electrical and mechanical components are of the age that replacement components are no longer available due to improved technology. Therefore, when select mechanical and electrical components fail, sometimes the only option is completely replace the system since repair components are no longer manufactured. Full-scale probabilistic reliability modeling was carried out for the major project components on the Cannelton project for project operations through the end of the study period, assumed to be 2060 for engineering reliability modeling. During the study period, long-term reliability concerns for the miter gates, operating machinery, hydraulic system, and electrical systems will need to be addressed through individual component replacement and/or full-scale major rehabilitation for the overall project. For more detail concerning the engineering reliability analysis and subsequent economic analysis, please refer to the engineering reliability sections of the Engineering Appendix and Economics Appendix.

It should be noted that the culvert valves at Cannelton warrant special concern since one of the main chamber culvert valves failed in 1999 due to fatigue/corrosion of the welded connection at the vertical rib/horizontal girder interface. Emergency repairs were made to the valve, but the damaged valve needs to be replaced. The other valves are also the same design and warrant immediate attention. For a more detailed analysis of the culvert valve analysis, refer to the reliability section of this appendix.

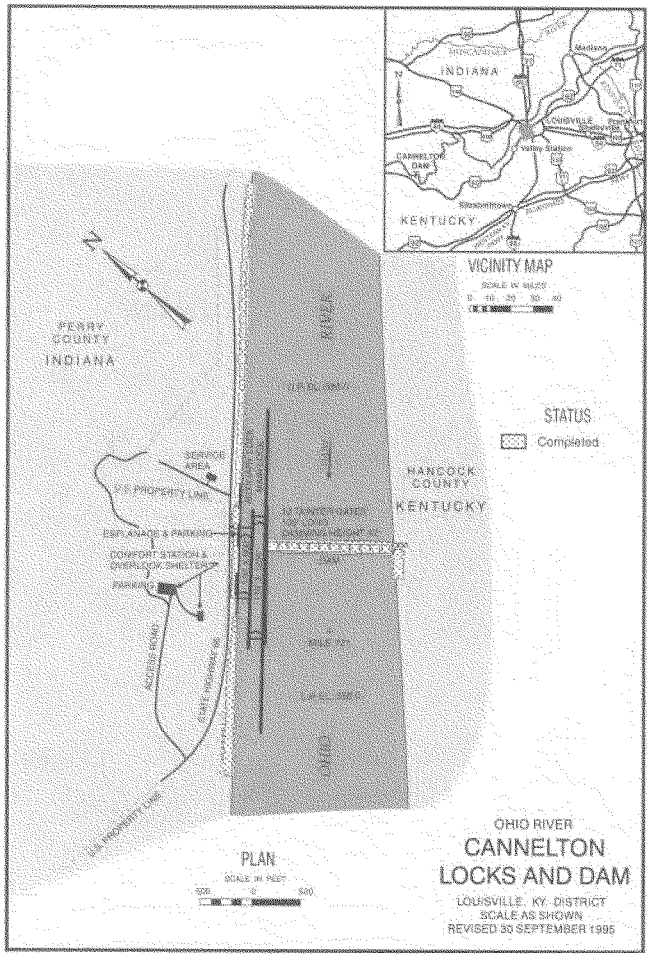

Figure ED 4-40. Cannelton Locks and Dam Project Layout

There is another major concern associated with the Cannelton project. It is the stability of the dam under seismic loading. The Cannelton project is situated in southwest Indiana, which is influenced by both the Wabash fault zone, as well as the New Madrid fault zone. During a recent investigation of the stability of the Cannelton dam on another project evaluating a potential dam retrofit for hydropower, it was determined that select dam sections at Cannelton do not meet current day deep-seated sliding stability criteria under seismic loadings. Therefore, the Louisville District is planning on initiating a Dam Safety Assurance Report to retrofit the dam with rock anchors at Cannelton to meet current day stability criteria. This was not investigated as part of the ORMSS because the engineering team did not look at extreme loading events

such as earthquakes and floods as per HQUSACE guidance. However, it is important to note from an overall project perspective that this issue is being addressed at Cannelton.

4.18 NEWBURGH LOCKS AND DAM

4.18.1 General Background Information - Newburgh

The Newburgh Locks and Dam are located on the Ohio River near Newburgh, Indiana, at mile 776.1 below Pittsburgh, Pennsylvania. It is about 16 miles upstream from Evansville, Indiana. The navigation locks are located on the right descending bank or Indiana side of the river. The upper pool maintained above the dam extends upstream for a distance of 55.4 miles to the Cannelton Locks and Dam at mile 720.7. Newburgh Locks and Dam was authorized as a replacement for existing Locks and Dams 46 and 47 on April 24, 1962, by Secretary of the Army under authority of Section 6 of the Rivers and Harbors Act approved March 3, 1909. Construction or the Newburgh Locks began in June 1966 and were placed in operation in December 1969. Dam construction began in June 1970 and the pool was raised to final level with the dam completion in 1975. The most significant change was an addition of a centralized control station on top of the lock operations building in 1980. Lock operators do a major portion of the lock and dam operations from the central control station. The lock operators can view eleven miles of river from the top of the building. The Newburgh project is essentially a replica of the John T. Myers project, which is the next lock project downstream, with site-specific changes for dam configuration.

4.18.2 Project Layout - Newburgh

The project is a high lift dam with two adjacent parallel locks, which is similar to the majority of other Ohio River navigation projects. A recent aerial photograph is shown in Figure ED 4-41 and a site plan/vicinity map is shown in Figure ED 4-42.

The dam consists of a non-navigable, gated-crest type structure 1,152.5 feet long and a fixed-weir navigable section 236 feet long terminating within natural ground on the left bank, or Kentucky side of the river. There are nine tainter gates 110 feet wide by 32 feet in height supported by concrete piers. The fixed-weir section is composed of a 13-foot high concrete crest structure over concrete-capped sheet pile cells. A concrete-capped sheet pile cutoff wall extends from the end of the weir section further into the bank. The gated section of the dam, including the upstream section of the locks, is topped with a prestressed concrete service bridge and includes a crane for positioning the upstream emergency bulkheads.

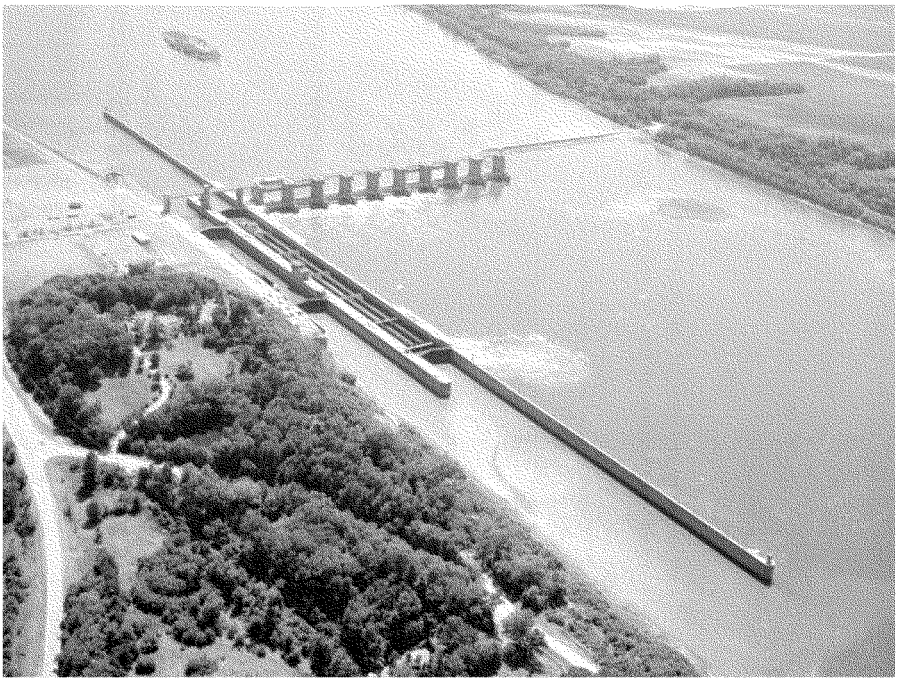

Figure ED 4-41. Aerial Photograph of Newburgh Locks and Dam

The two adjacent parallel lock chambers are located along the Indiana shore. The main lock chamber has clear dimensions of 110 feet by 1,200 feet and the auxiliary lock has clear dimensions of 110 feet by 600 feet. Normal upper pool is at elevation 358.0. Normal lower pool (John T. Myers Pool) is elevation 342.0. Thus, the lift is 16 feet at normal pool levels, which makes it the smallest lift of the Louisville District locks on the Ohio River. Two sets of hydraulically operated steel miter gates are provided for each lock. Each lock has provisions immediately upstream of the upper miter gates for the placement of open truss emergency bulkheads. Provisions for maintenance bulkheads are also provided immediately downstream of each set of miter gates. Aluminum truss maintenance bulkheads are available for dewatering and can be used at Newburgh. By use of bulkheads, each of the culvert valves, miter gates and the entire lock chamber are designed for dewatering to facilitate maintenance. When the lock is closed due to high water, navigation may pass by the structure over the fixed weir between the gated section and the left bank, although this is a rare occurrence.

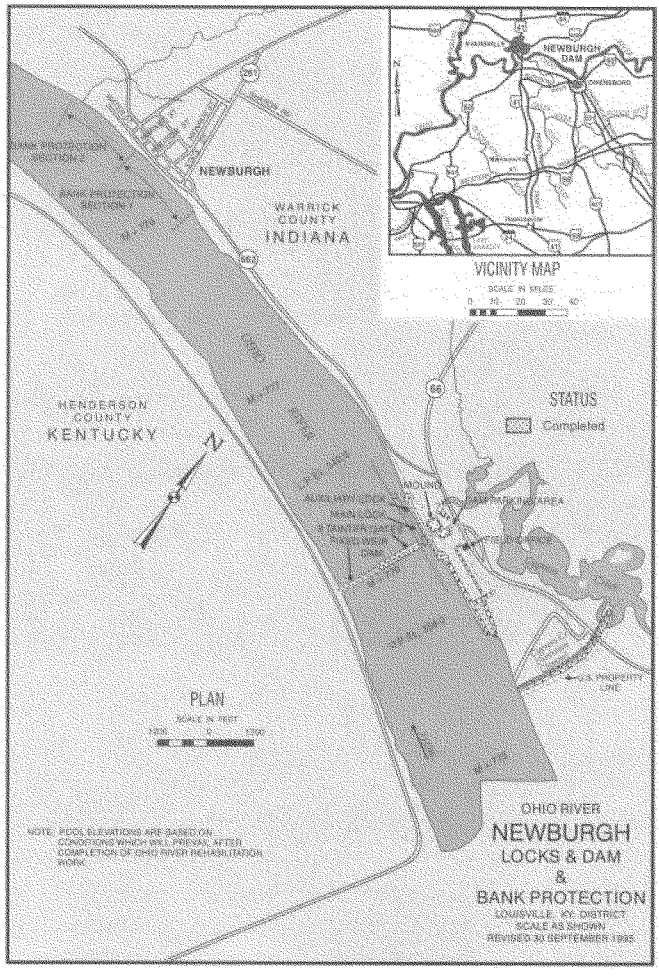

Figure ED 4-42. Project Layout for Newburgh Locks and Dam

4.18.3 Assessment of Concerns and Needs - Newburgh

The major concern associated with the Newburgh project is similar to many of the other Ohio River projects, decreasing reliability of major features coupled with reduced auxiliary lock chamber capacity (as described in Section 4.2 of this appendix). The major navigation components associated with project are approaching 40 years of service with a high historic level of traffic. The main chamber availability is even more of a concern at Newburgh because it represents one of the highest traffic level projects on the Ohio River where the auxiliary lock chamber is not authorized for a 600-ft extension (since the John T. Myers and Greenup auxiliary lock chambers were authorized for extensions as part of the Water Resources Development Act of 2000). Reduced reliability of the main lock

chamber operating components during the study period was determined through the analytical engineering reliability modeling. Refer to that portion of this appendix for a detailed description of the engineering reliability analysis at Newburgh. The economic effects of reduced future reliability is detailed in the Economics Appendix. This is the major contributor when assessing the need for other improvements at Newburgh, such as auxiliary lock extensions similar to those authorized at John T. Myers and Greenup Locks and Dams.

4.19 JOHN T. MYERS LOCKS AND DAM

4.19.1 General Background Information - John T. Myers

John T. Myers Locks and Dam (J.T. Myers), formerly Uniontown Locks and Dam, was renamed on October 12, 1996, by direction of Public Law 104-303. The project is located on the Ohio River about 3½ miles downstream from Uniontown, Kentucky, at mile 845.9 below Pittsburgh, Pennsylvania. The navigation locks are located on the right bank or Indiana side of the river. The upper pool maintained above the dam extends upstream for a distance of 69.9 miles to the Newburgh Locks and Dam at Mile 776.1. The project was authorized as replacement for existing Locks and Dam 48 and 49 on September 17,1958, by Secretary of the Army under authority of Section 6 of the Rivers and Harbors Act approved March 3, 1909, as amended. Construction of Uniontown Locks started in June 1965 and were completed and placed in operation in December 1969. Dam construction started in May 1970, pool raised to final level in January 1975, and completed in 1977. It is essentially a replica of the Newburgh Locks and Dam, the adjacent project upstream of John T. Myers, with modifications to the dam as necessary with respect to fixed weir configuration and dam gate layout.

4.19.2 Project Layout - J.T. Myers

The project is a high lift dam with two adjacent parallel locks. A recent aerial photograph is shown in Figure ED 4-43 and a site plan/vicinity map is shown in Figure ED 4-44. Note the location of Wabash Island downstream of the project, as well as the mouth of the Wabash River just downstream of the project. Both of these have a significant impact on navigation conditions around this project.

The dam consists of a non-navigable gated-crest type structure 1,277.4 feet long, a fixed weir section 2,239 feet long, and a concrete-capped sheet pile cutoff wall and dike 300 feet long terminating in natural ground on the left bank or Kentucky side of the river. There are 10 non-submergible tainter gates 110 feet by 32 feet high supported by concrete piers. The fixed weir section is composed of an 11-foot high concrete crest structure over concrete filled sheet pile cells. A concrete-capped sheet pile cutoff wall extends from the end of the weir section further into the bank. The gated section of the dam, including the upstream section of the locks, is topped with a prestressed concrete/service bridge and includes a crane for lifting the upstream emergency bulkheads.

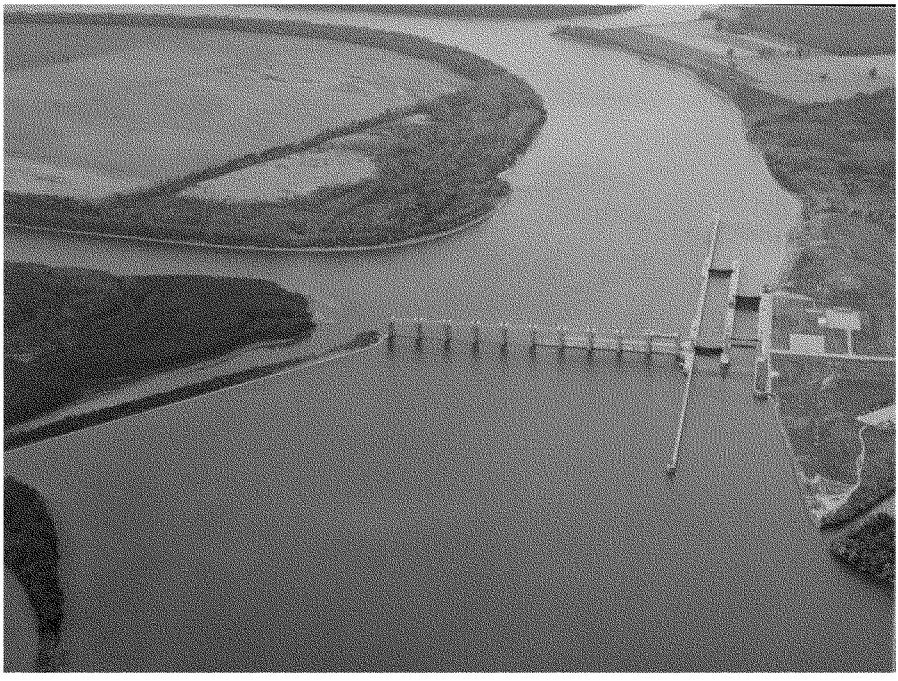

Figure ED 4-43. Aerial Photograph of J.T. Myers Locks and Dam

The two adjacent parallel lock chambers are located along the Indiana shore, the main lock chamber having clear dimensions of 110 x 1,200 feet and the auxiliary lock 110 x 600 feet. The lock chambers have an 18-foot lift at normal pool with normal upper pool at elevation 342.0 and normal lower pool (Smithland pool) at elevation 324.0. Two sets of hydraulically operated steel miter gates are provided for each lock. Each lock has provisions immediately upstream of the upper miter gates for the placement of open truss emergency bulkheads. Provisions for maintenance bulkheads are provided immediately downstream of each set of miter gates. Mobile maintenance bulkheads are available throughout the Louisville District for the 110-ft wide lock chambers. By the use of bulkheads, each of the culvert valves, the miter gates and the entire lock chamber are designed for dewatering to facilitate maintenance. When the lock is closed due to high water, navigation may pass by the structure over the fixed weir between the gated section and the left bank, although this is rarely done given the height of the lock walls.

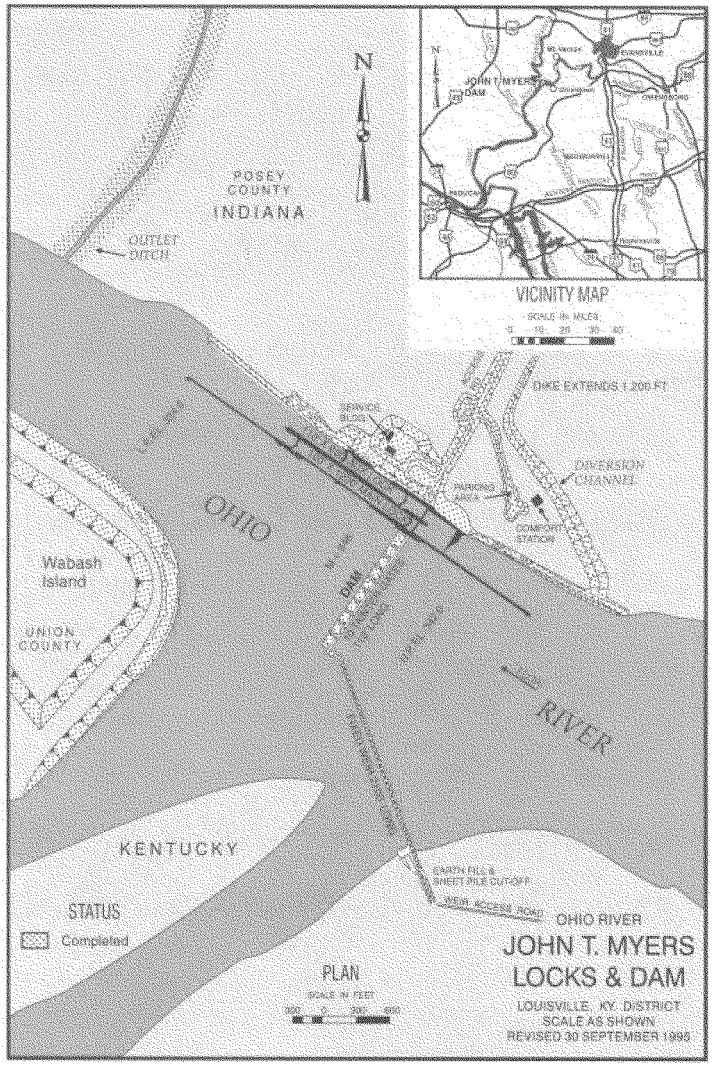

Figure ED 4-44. J.T. Myers Locks and Dam Project Layout

4.19.3 Assessment of Concerns and Needs - J.T. Myers

There are two major concerns regarding the J.T. Myers site. The first relates to the condition of the dam relative to the stilling basin and stability of the monoliths. An on-going major rehabilitation study of the J.T. Myers dam is scheduled for completion in late spring 2006. This report will detail the reliability issues associated with the dam. One problem is erosion of the stilling basin structure below the tainter gates. The

concrete section is being eroded out and currently can not be repaired because it is below the dewatering slots for the dam. The secondary issue is the stability of the monoliths for both seismic load cases, as well as meeting criteria for other load cases. Recommended repair options included procuring a specialized dewatering bulkhead to make repairs to the stilling basin floor and anchoring the monoliths. These are detailed in the J.T. Myers Dam Major Rehab Report.

The other major concern at J.T> Myers is associated with inadequate auxiliary lock chamber capacity and is being addressed with the J.T. Myers Locks Improvements Project, which was authorized as part of WRDA 2000. When completed, this project will have twin 1200-ft lock chambers which essentially eliminates the concerns regarding insufficient auxiliary chamber capacity. The project was authorized as part of an interim report on the ORMSS and also included a capacity improvement project at Greenup Locks and Dam in the Huntington District. Refer to the Greenup section of this engineering appendix for more detail associated with that project. Both the J.T. Myers Locks Improvements Project and the Greenup Lock Extension Project are currently in design. Anticipated "on-line" dates for these projects are currently estimated to be around 2010 pending appropriate funding levels for design and construction activities.

4.19.4 Overview of J.T. Myers Locks Improvements Project

There are several features associated with the J.T. Myers Locks Improvements Project. The primary feature is an extension of the auxiliary lock chamber from 600-ft to a nominal 1200-ft length. This will eliminate the need for "double-cutting" of tows during closures of the existing main chamber. Other major improvements include a supplemental filling and emptying (F/E) system to provide water flow into and out of the extended end of the lock chamber, new downstream miter gates, new filling and emptying culvert valves for the supplemental F/E system, as well as floating approach wall extensions for the upper end of the project. In addition, new lower land and middle approach walls are also provided for the authorized project to improve navigation approach conditions on the lower end of the newly extended lock chamber. Finally, aquatic mitigation features, as well as supporting construction facilities (resident engineer's office, bank line modifications, etc.) to support the project are also included. Many of the project features (land wall extension, approach walls, etc...) utilize innovative construction techniques such as float-in and lift-in construction in order to minimize on-site interference with navigation traffic, as well as reduce costs and time when compared to traditional methods. The authorized cost of the John T. Myers Locks Improvements Project was approximately $182 million in year 2000 dollars. Refer to Figure ED 4-45 for a plan view showing the major project improvements for the authorized project at J.T. Myers.

Currently, there are several potential cost saving features being evaluated as part of on-going design with the J.T. Myers Locks Improvement Project. These were done as part of an overall evaluation that investigated how to reduce construction costs for lock extension projects since there are other projects that could potentially benefit from extensions of the shorter auxiliary lock chambers. Physical hydraulic modeling at ERDC-WES was undertaken to determine more cost effective way to provide supplemental filling and emptying to the lower end of the extended lock chamber. A 1:25 scale F/E model was built replicating the J.T. Myers project. Several potential

alternatives were evaluated for the supplemental F/E system, but the one that provided the best combination of cost savings and performance was a through-the-sill filling system coupled with most of the existing emptying features of the authorized project. A basic description of the planned changes include providing twin supplemental culverts that go through the upper sill and rest on the lock floor before transitioning into the new lower land wall. Reverse tainter filling and emptying valves are provided in the new lower land wall. A downstream lateral diffuser system is also provided to better distribute water flow in the lower end. Finally, a landside outlet diffuser empties the lower half of the extended lock chamber landward of the new lower land approach wall.

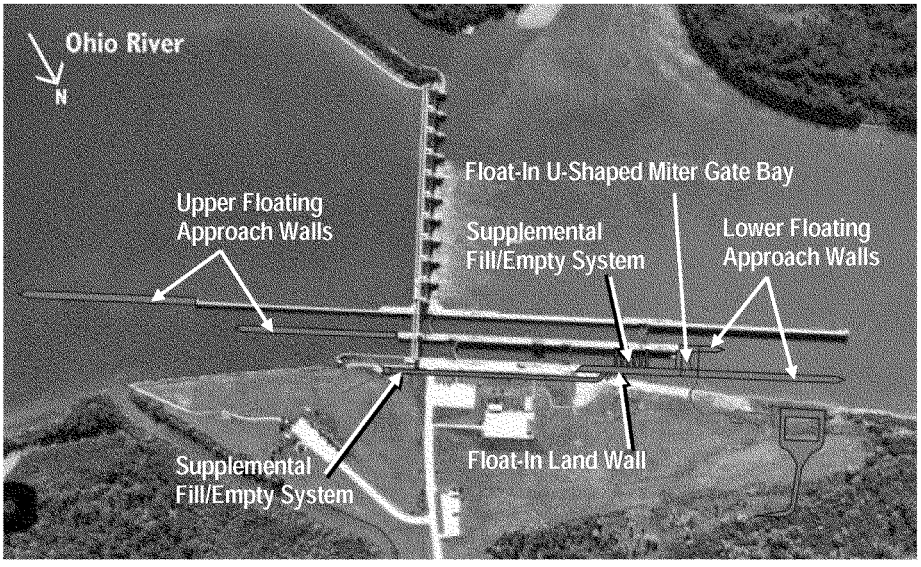

Figure ED 4-45. Authorized John T. Myers Locks Improvements Project Features

The diffuser system, land wall culvert, and downstream lateral system were part of the authorized lock extension plan at J.T. Myers. The big difference between the two F/E systems is the elimination of the long wrap around culvert tucked behind the existing land wall as shown in Figure ED 4-47. The adequate clearance at J.T. Myers affords the opportunity to eliminate this costly excavation and dewatering along with the features required to put that system in place. A plan view of the alternative supplemental F/E system envisioned at J.T. Myers is shown in Figure ED 4-46. This plan is still undergoing refinement, but the basic premise should remain as the preferred option at J.T. Myers due to its cost savings, currently estimated to be approximately $15 million, compared to the wrap around system.

Additionally, a 1:100 scale navigation model is being tested at ERDC-WES looking at potential changes required for access and approach wall configurations at J.T. Myers as a result of the planned project changes. This portion of the authorized project also has a significant potential for savings since most project team members believed that

conservative approach wall extension lengths were provided as part of the authorized project. Initial indications from the 1:100 model results are that the authorized approach wall lengths are indeed longer than required for navigation conditions at J.T. Myers. The authorized project approach extension lengths were as follows: 960 feet on the upper river wall, 900 feet on the upper middle wall, 100 feet on the lower middle wall, and 700 feet on the lower land wall. After coordinating 1:100 model tests with the navigation industry, it appears as if only 500 feet is need on the upper river wall, 800 feet on the upper middle wall, and 400 feet on the lower land wall. The lower middle wall should remain at 100 feet. This is a savings of 860 linear feet of approach wall length that is currently estimated to save approximately $7 million when compared to the authorized project. Testing of the 1:100 navigation and 1:25 F/E models is continuing. Most of these tests are refinements to the basic plans described above.

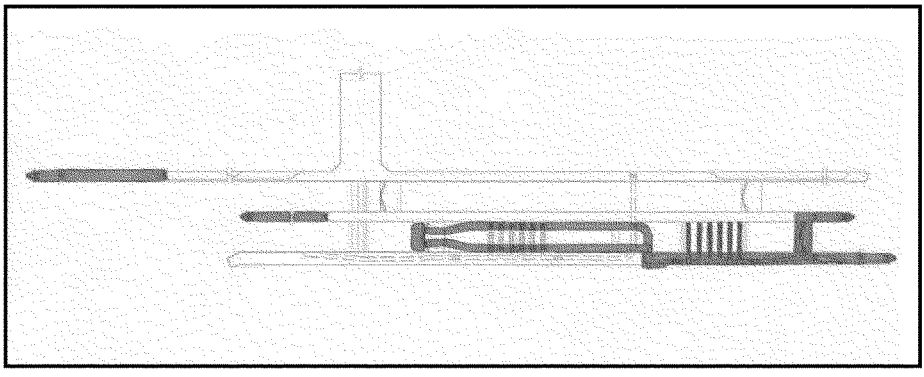

Figure ED 4-46. Alternative F/E System Features at J.T. Myers (Shown in Red)

4.20 SMITHLAND LOCKS AND DAM

4.20.1 General Background Information - Smithland

The Smithland Locks and Dam project is located on the Ohio River, at Mile 918.5, below Pittsburgh, Pennsylvania, 2 miles upstream from Smithland, Kentucky, where the Cumberland River joins the Ohio River and 16 miles upstream from Paducah, Kentucky where the Tennessee River joins the Ohio River. The upper pool extends upstream 72.5 miles to the J.T. Myers Locks and Dam project. The navigation locks are located on the right bank or Illinois side of the Ohio River. The project is a high lift dam with twin navigational locks.

The Smithland Locks and Dam was authorized on December 8, 1965, as a replacement for existing Locks and Dam 50 and 51, under authority of Section 6 of the Rivers and Harbors Act of March 3, 1909. Construction was started beginning with the locks in 1971, and dam structures in 1974. The locks were placed in operation in 1979 with the dam essentially completed in November 1980.

4.20.2 Project Layout - Smithland

The two Smithland Locks are each 110 feet wide and 1,200 feet long making it the only twin 1200-ft lock chamber project on the Ohio River, although this will change soon with construction at Olmsted and McAlpine and authorized lock extensions at J.T. Myers and Greenup. The overall length of the river lock wall, including the guard walls, is approximately three-quarters of a mile. Each miter gate leaf weighs approximately 250 tons. The miter gates and valve machinery are hydraulically operated. Each lock chamber requires eight minutes for filling and nine minutes for emptying for maximum pool differentials. A recent aerial photograph is shown in Figure ED 4-47 and a site plan/vicinity map is shown in Figure ED 4-48. A basic description of each main feature is provided below.

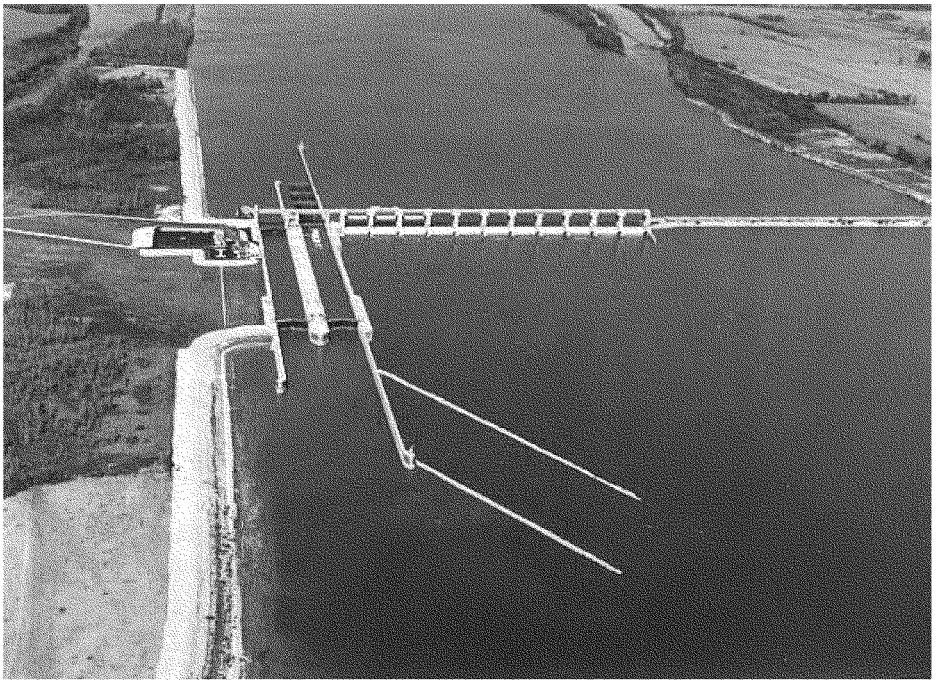

Figure ED 4-47. Aerial Photograph of Smithland Locks and Dam

The dam consists of a non-navigable gated-crest type structure, a fixed weir section, and a concrete-capped sheet cutoff wall and dike. The gated structure is 1,390 feet long with 11 nonsubmergible tainter gates. Each gate is 110 feet long by 36 feet high. Pier 1 ties into the river wall of the lock chamber and pier 12 ties into the fixed weir. The fixed weir section is approximately 1,740 feet long with 22 circular sheet pile cells and connecting arcs. Cell W1 ties to the gated structure. The fixed weir has a uniform crest elevation of 326.0. A prestressed concrete service bridge traverses the gated dam structure and the approaches to the locks. The bridge provides access to and

rails for the bulkhead hoist-crane. This crane is used for the handling and placement of the emergency bulkheads in either lock approaches or the gate bays. In 1995 construction of the prototype wicket test facility was added to test the design of hydraulically operated wicket gates for the proposed Olmsted Locks and Dam project. Five, 9'-7" wide by 25'-6" long wickets are installed at the facility. A 1,200-foot approach channel was dug connecting the upper pool to the facility and an 800-foot retreat channel connected the lower pool. Completion of the test facility was in August 1995. The site was abandoned with all five wickets locked in the raised position with four-inch gaps between each wicket. The tops of the wickets are set at elevation 326.00. A pedestrian bridge crosses the channel allowing access to the Kentucky side of the river. The Olmsted Prototype facility is not shown in the aerial photograph or project layout figures since this post dates the times for both the aerial photograph and site layout map.

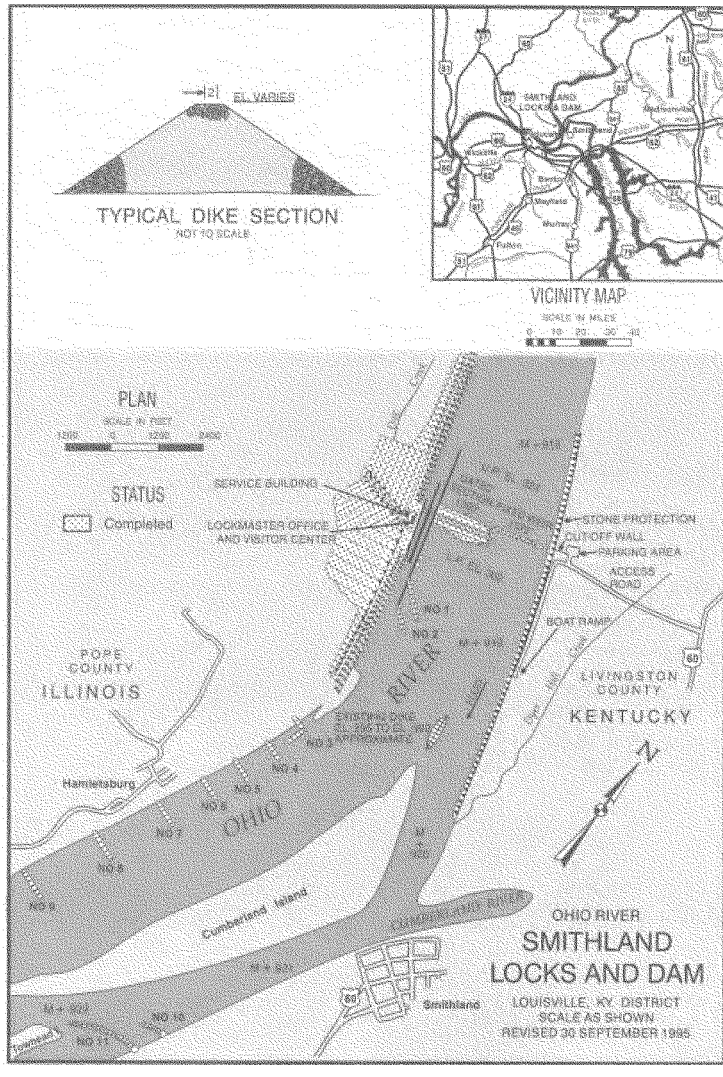

Figure ED 4-48. Project Layout for Smithland Locks and Dam

The locks are twin parallel chambers located along the Illinois bank. Each lock is 110 by 1,200 feet and has a 22-foot lift at normal pool. Two sets of hydraulically operated all-welded steel miter gates are provided for each lock. Each lock has provisions, immediately upstream and downstream of the miter gates, for the placement of the open truss, emergency bulkheads. The same bulkhead sections are used for the dam tainter gates. By the use of these bulkheads, and closure of the culvert valves, the entire lock chamber can be dewatered for inspection and maintenance. These locks are equipped with a fire protection system, which can spray water on the lock chamber of all

miter gates. Normal upper pool is at elevation 324.0. Normal lower pool (Olmsted Pool) is anticipated to be elevation 302.0, once Olmsted is complete. Thus, the lift is 22 feet at normal pool levels is expected.

4.20.3 Assessment of Concerns and Needs - Smithland

Smithland is a unique project from the standpoint that it has had twin 1200-ft lock chambers since it was constructed approximately 25 years ago. The project sees the most operational cycles when combining both lock chambers together, however, directional locking procedures keeps one chamber from receiving too many of the lock cycles. Currently, there is adequate capacity when one of the 1200-ft lock chambers is closed for maintenance. However, this could potentially change in the future depending upon traffic levels. It is in a key shipping location near the conjunction of the Ohio, Mississippi, and Tennessee Rivers. It is crucial that this overall project stays reliable given current and future project traffic.

The major structural concern at Smithland now is the condition of the culvert valves. The valves are original, but one of the valves failed in 1997. A detailed explanation of the valve failure is described in the reliability section of this appendix, but it was essentially a fatigue/corrosion failure of the welded connection at the vertical rib and horizontal girder interface. The valve suffered major damage, but was salvaged and emergency repairs were made. Fortunately, this only caused a short shutdown of the lock chamber as there are two filling and emptying valves each for both 1200-ft lock chambers at Smithland. After a short shutdown period, the valve was repaired on-site by operating the chamber at ½ filling and emptying speed until the repairs to the damaged valve could be completed. The remaining valves at Smithland showed signs of pending damage as well, but temporary repairs were made to improve their reliability for the short-term. Full-scale reliability modeling was carried out on the major components (miter gates, culvert valves, operating machinery, etc.) and there are anticipated reliability problems besides the culvert valves during the study period. These are specifically addressed in the reliability section of this appendix.

4.21 OLMSTED LOCKS AND DAM

4.21.1 General Background Information - Olmsted

Olmsted Locks and Dam is located approximately 1.8 miles below existing Locks and Dam 53 at Ohio River mile 964.4. It is located just upstream of the Ohio Rivers confluence with the Mississippi River near Cairo, Illinois. The Olmsted project was authorized by the October 17, 1988 WDRA, PL 100-676. It will replace low-lift Locks and Dams 52 and 53, providing a navigation pool to the next project upstream, Smithland Locks and Dam.

4.21.2 Project Layout - Olmsted

The project consists of twin 110-ft wide by 1200-ft long lock chambers located on the Illinois side of the Ohio River. The dam will consist of tainter gates and a boat-

operated wicket navigable pass that can be raised or lowered for navigation purposes. Tows will bypass the locks and go over the top of the dam during high water, approximately 60 percent of the year. An additional 425 feet of fixed weir ties the dam to the Kentucky shore. An artist's rendering of the completed project is shown in Figure ED 4-49. There have been some minor modifications to the rendering, however, the basic layout remains unchanged.

4.21.3 Current Status of Project

There are four major construction contracts for the Olmsted project. The first was the cellular cofferdam. The cellular cofferdam and base lock foundation preparation was completed between 1993 and 1995. The second major construction contract completed was for building the twin lock chambers. The locks were constructed between 1996 and 2001. The third major construction contract was for the floating approach walls and nose piers. The approach wall pontoons were constructed off-site and floated into place. The nose piers for the floating pontoons and lower land guide wall were completed on-site. This approach wall contract was recently completed. Construction on the approach walls was started in 1999. The final contract will be for the construction of the dam. The final major contract for Olmsted is the construction of the dam. This contract was recently awarded and construction has started on this last segment of the project. Due to funding constraints and other issues, it is anticipated that the project will be completed sometime between 2012 and 2015.

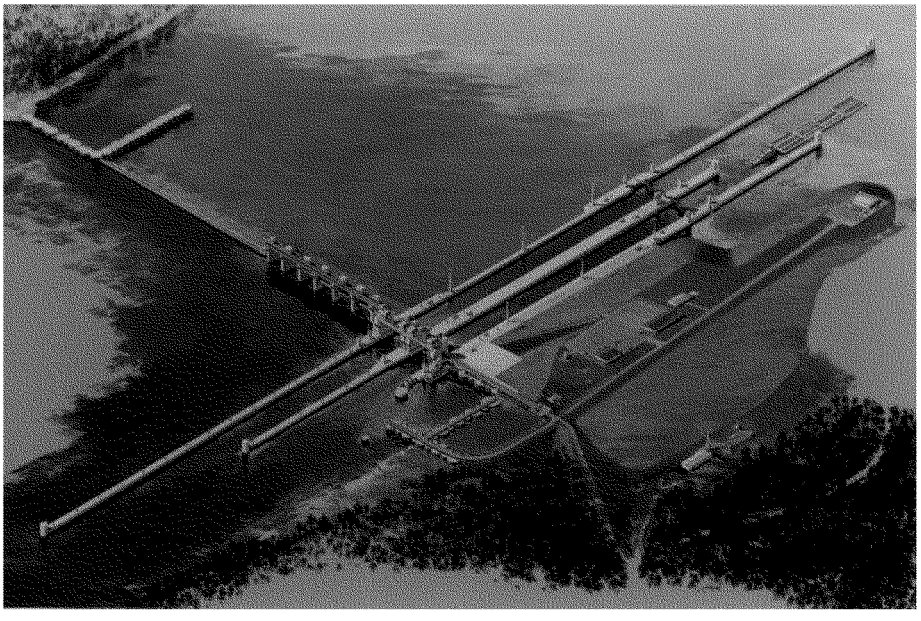

Figure ED 4-49. Rendering of Completed Olmsted Locks and Dam Project

Section 5
LOCK AND DAM RISK AND RELIABILITY MODELING

This section describes the effort involving the engineering and economic modeling of major lock and dam components for ORMSS. The purpose of engineering reliability modeling is to determine the long-term performance of major lock and dam components. Additionally, the analysis predicts the consequences of unsatisfactory performance from both a navigation delay standpoint as well as repair cost standpoint as structures age and see increased operating cycles. The engineering reliability and economic risk assessment of these components play an important role in the development of net benefits for the various alternatives being considered.

5.1 COMPONENTS REQUIRING RELIABILITY ANALYSIS

The initial effort of the overall reliability assessment of the lock and dam was to determine which components should have reliability analysis conducted on them. Since there are several components that can cause disruption of navigation service and/or be very costly to replace, a process of eliminating "minor" components had to be developed. Therefore, the team developed a two-phase screening process that eliminated several minor components from consideration for reliability analyses. This screening process also made the overall effort manageable in terms of available funding and time constraints.

5.1.1 Selection of Components

The initial effort on the ORMSS was for a team of engineers, one from each of the three districts with navigation locks on the main stem of the Ohio River, to go out and inspect every lock and dam on the Ohio River to determine their condition relative to one another. Included in this effort was interviewing personnel at the project site in order to get as much information as possible. This group was kept as consistent as possible in order to have a fair rating of the locks relative to one another. The second step was for the same group of engineers to review the plans and Periodic Inspection Reports for each of the sites. From this effort, an initial master list of 150 components was developed for screening. This list was developed to represent all the sites on the Ohio River. The list was screened in two stages. The first phase screening process was used to investigate the relative importance of a component in terms of the overall lock operation. The second phase screening investigated the overall importance of the component from both a site specific and an overall Ohio River systems standpoint.

First Phase Screening

A sample of the original list of lock components, shown in Table ED 5-1, was screened based upon their relative importance to the overall operation of the lock. A multi-district, multi-discipline team of engineers screened the original list of components as part of the first phase. If a component was considered non-essential or is typically repaired as part of routine maintenance,

it was screened out during the first phase. If any of the following reasons were applicable, the component was screened out first phase:

Redundancy. The component's function could be accomplished by other means or there are numerous components that would have to perform unsatisfactorily at the same time to be considered a significant problem. An example would be that line hooks could be used instead of check posts if necessary.

Item #	Component	Component Use	Discipline	Screened Out	Reason for Screen Out
64	Chamber Monolith Stability	Lock	Struct/Geotech	No	
65	Miter Gate Monolith Stability	Lock	Struct/Geotech	No	
66	Concrete Horizontal Surfaces	Lock/Dam	Structural	No	
67	Guardwall/Guidewall Stability	Lock	Struct/Geotech	No	
68	Fixed Weir Stability	Dam	Struct/Geotech	No	
69	Sheet Pile Cellular Structures Stability	Lock	Struct/Geotech	No	
70	Pile Founded Structures Stability	Lock/Dam	Struct/Geotech	No	
71	Dam Pier Stability	Dam	Struct/Geotech	No	
72	Mass Concrete	Lock/Dam	Structural	No	
73	Overflow Spillway Stability	Dam	Struct/Geotech	No	
74	Miter Gate Sill Stability	Lock	Struct/Geotech	No	
75	Dam Gate Sill Stability	Dam	Struct/Geotech	No	
76	Retaining Wall Stability	Lock/Dam	Struct/Geotech	No	
77	Air Conditioning Units	Miscellaneous	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
78	Heating/Furnace Units	Miscellaneous	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
79	Raw Water Pump	Miscellaneous	Mech./Elec.	Yes	Handled through normal maintenance.
80	Strainer	Miscellaneous	Mech./Elec.	Yes	Handled through normal maintenance.
81	Bubbler System	Lock/Dam	Mech./Elec.	Yes	Redundant, other means available to serve purpose.
82	Fuel Oil Transfer Pump	Miscellaneous	Mech./Elec.	Yes	Handled through normal maintenance.
83	Water Heaters	Miscellaneous	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
84	Exhaust Fans	Miscellaneous	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
85	Service Building Crane	Maintenance	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
86	Piggy Back Crane	Maintenance	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
87	Dam Elevator Mechanical	Dam	Mech./Elec.	Yes	Redundant, other means available to serve purpose.
88	Closed Circuit TV System	Lock/Dam	Mech./Elec.	Yes	Redundant, other means available to serve purpose.
89	Batteries	Miscellaneous	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
90	Cathodic Protection	Lock	Mech./Elec.	Yes	Handled through normal maintenance.
91	Anodes	Lock/Dam	Mech./Elec.	Yes	Handled through normal maintenance.
92	Siren System/Air Whistle	Lock/Dam	Mech./Elec.	Yes	Not considered critical to operation of lock and dam.
93	Panel Heater	Miscellaneous	Mech./Elec.	Yes	Handled through normal maintenance.
94	Control Building Mechanical	Lock/Dam	Mech./Elec.	Yes	Handled through normal maintenance.
95	Control Building Electrical	Lock/Dam	Mech./Elec.	Yes	Handled through normal maintenance.
96	Service Building Misc. Mechanical	Maintenance	Mech./Elec.	Yes	Handled through normal maintenance.
97	Service Building Misc. Electrical	Maintenance	Mech./Elec.	Yes	Handled through normal maintenance.

Table ED 5-1. Sample of Master List of Components for Reliability Screening

Non-critical. The component was not considered critical to the overall operation of the lock. An example is wall armor along monolith vertical face.

Routine Maintenance. If the component were to perform unsatisfactorily in any manner, it would always be repaired as part of normal maintenance. An example would be handrails, grating, etc.

Reliable Component. The likelihood of unreliable performance was considered remote. An example is culvert bulkhead sill stability.

Any components that did not fall into one of these screening criteria were screened again during the second phase screening process. Out of 150 total initial components, a total for all Ohio River locks, 60 survived the first screening phase. Since there was not enough funding or time to warrant reliability models for 60 different components, the first phase survivors were re-screened during the second phase. This phase is described in the next section.

Second Phase Screening

Originally, all components that survived the first phase of screening were subjected to a second level screening. The second phase screening process was developed to incorporate the importance of a particular component not only on a site-specific basis, but also on a systems basis in relation to other lock and dams on the Ohio River. Sixty lock components survived the first phase screening process out of 150 initial components. These 60 survivors were next rated by the same multi-district/multi-discipline team of engineers on a scale of 1 to 3 based upon six categories: *System Number, Component Site Consequence, Component Site Cost, Component System Cost, System Consequence, and Likelihood of Problems*. Some of the categories based their results upon answering questions about the performance of the component. A description of each category is detailed below.

Ranking	Description
1.0	Low, No, Minor
2.0	Medium, Average
3.0	High, Yes, Major

System Number. Number of sites of locations where this component was present within the Ohio River Main Stem lock and dam system.

Component Site Consequence. From a site-specific standpoint, how would navigation traffic be directly and immediately affected by the unsatisfactory performance of the component. Is there a lack of redundancy for this component from a site-specific standpoint?

Component Site Cost. From a site-specific standpoint, does the total number of the components reflect a major rehab/replacement cost relative to the site?

Component System Cost. From an overall system standpoint, does the total number of this component reflect a significant rehabilitation/replacement cost on the entire system?

System Consequence. From an overall standpoint, if this component were to perform unsatisfactorily, would navigation be impacted significantly?

Likeliness of Problems. Is it likely that the component would need repairs based upon past performance or suspected degradation?

A special ranking system was developed to assist in ranking the system categories: *System Consequence, Component System Cost,* and *System Number*. The ranking system is shown in Figure ED 5-1 on the following sheet. The values that were computed from that sheet were input into the overall ranking sheet for the three categories for the Phase 2 rating, as shown in Table ED 5-2.

The results for each of the six categories were added together to determine a final ranking. After reviewing the overall rankings, it was determined that there was a general break in the rankings for components around the 12-13 range. Therefore, the engineering team decided that components which had a phase 2 overall ranking of 13 or above (out of a maximum of 18), would have reliability analyses completed for them, assuming budget and schedule allowed as the study progressed. The results of the Phase 2 screening are depicted in Table ED 5-2.

There were a total of 20 components that survived both the first and second phase screenings. This represents the original list that was intended for reliability modeling during the early phases of the ORMSS when budgets, scheduling, and overall direction were still being developed for all parts of the study. The original list of components to be analyzed through probabilistic means is shown on the following page.

Original List of Components for Reliability Model Development

1. Horizontally-framed Miter Gates
2. Vertically-framed Miter Gates
3. Miter Gate Anchorage
4. Reverse Tainter Gate Culvert Valves
5. Butterfly Valves
6. Reverse Tainter Culvert Valve Anchorage
7. Chamber Monolith Stability
    a. Unanchored Lock Wall Monoliths
    b. Anchored Lock Wall Monoliths
8. Miter Gate Monolith Stability
9. Guard/Guide Wall Stability
    a. Gravity Structures
    b. Pile-Founded
10. Miter Gate Sill Stability
    a. Unanchored Sills
    b. Anchored Sills
11. Hydraulic Power System (Mechanical)
12. Power and Control Equipment (Electrical)
13. Dam Tainter Gates
14. Dam Tainter Gate Anchorage
15. Dam Roller Gates
16. Dam Vertical Lift Gates
17. Dam Pier Stability
18. Fixed Weir Stability
19. Dam Gate Sill Stability
20. Sheet Pile Cellular Structure Stability

Further Screening and Prioritization of Model Development

It was intended that reliability models would be developed for all 20 survivors of the screening process as listed in Table ED 5-2 for the ORMSS. As model development progressed, a few changes to the original list of 20 survivors were made based upon judgment, study schedule, and available funds. For example, the reverse tainter gate culvert valve anchorage model was lumped into the overall reverse tainter valve model. Therefore, a single model covered both. Additionally, the butterfly valves were incorporated as part of the mechanical model for the lock since there was available data for the performance of butterfly valves relative to reliability analysis. Also, it was determined that a separate miter gate anchorage model was not necessary since previous analyses indicated the critical element to be the I-bars. Since the I-bars are switched out and maintained as part of normal maintenance, the component was eliminated from consideration. Also, there were two types of reverse tainter culvert valve models that had to be developed, one for horizontally-framed valves and the other for vertically-framed valves.

	Individual Lock and Dam Component Data							1994 Traffic Information		
	Miter Gates		Culvert Valves		Dam Gates			Individual Site		
Project Site	Hrz. Framed	Vert. Framed	Butterfly	R. Tainter	Roller	Tainter	Vertical Lift	'94 kilotons	% Total	Conseq. Rank
Emsworth	2	2	44	-	-	-	13	24,272	2.24%	**1.0**
Dashields	2	2	6	-	-	-	-	25,602	2.36%	**1.0**
Montgomery Island	2	2	6	-	-	-	10	27,313	2.52%	**1.5**
New Cumberland	4	-	-	6	-	11	-	37,272	3.44%	**1.5**
Pike Island	4	-	-	6	-	9	-	43,643	4.03%	**2.0**
Hannibal	4	-	-	6	-	8	-	47,783	4.41%	**2.0**
Willow Island	4	-	-	6	-	8	-	45,802	4.23%	**2.0**
Belleville	4	-	-	6	-	8	-	48,641	4.49%	**2.0**
Racine	4	-	-	6	-	8	-	49,845	4.60%	**2.0**
Robert C. Byrd	4	-	-	6	8	-	-	56,079	5.18%	**2.0**
Greenup	4	-	-	6	-	9	-	68,695	6.34%	**2.5**
Meldahl	4	-	-	6	-	12	-	64,627	5.97%	**2.5**
Markland	4	-	-	6	-	12	-	60,011	5.54%	**2.5**
McAlpine	4	-	-	8	-	9	-	61,943	5.72%	**2.5**
Cannelton	4	-	-	6	-	12	-	64,257	5.93%	**2.5**
Newburgh	4	-	-	6	-	9	-	76,779	7.09%	**3.0**
Uniontown	4	-	-	6	-	10	-	85,718	7.92%	**3.0**
Smithland	4	-	-	8	-	11	-	93,337	8.62%	**3.0**
Olmsted	4	-	-	8	-	5	-	101,267	9.35%	**3.0**
Component Totals	**70**	**6**	**56**	**102**	**8**	**141**	**23**	**1,082,886**		
% of Total	**92%**	**8%**	**35%**	**65%**	**5%**	**82%**	**13%**			
System Cost Rank	**3.0**	**1.0**	**2.0**	**2.5**	**1.0**	**3.0**	**1.5**			
Sites w/ Compnt.	**100%**	**16%**	**16%**	**84%**	**5%**	**79%**	**11%**			
System # Rank	**3.0**	**1.5**	**1.5**	**3.0**	**1.0**	**3.0**	**1.0**			

System Cost Rank	
Overall %	Cost Rank
0 - 10%	1.0
11 - 25%	1.5
26 - 40%	2.0
41 - 65%	2.5
66 - 100%	3.0

System Number Rank	
Overall %	Number Rk.
0 - 15%	1.0
16 - 30%	1.5
31 - 45%	2.0
45 - 60%	2.5
61 - 100%	3.0

Consequence Ranking	
Site Overall %	Conseq. Rk.
0 - 2.5%	1.0
2.51 - 4.0%	1.5
4.01 - 5.5%	2.0
5.51 - 7.0%	2.5
Above 7.0%	3.0

Figure ED 5-1. Phase 2 Ranking Criteria

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Type of Component	Engineering Discipline	System Number	Site Specific Consequence	Site Specific Cost	System Cost	System Consequence	Likelihood of Problems	Overall Ranking	Phase 2 Screening Results
Horiz. Framed Miter Gates	Structural	3.0	3.0	3.0	3.0	3.0	3.0	18.0	Reliability Analysis
Vert. Framed Miter Gates	Structural	1.5	3.0	3.0	1.0	1.5	3.0	13.0	Reliability Analysis
Lock Emergency Gates	Structural	2.0	2.0	3.0	1.0	1.0	2.0	11.0	Screened Out
Reverse Tainter Valves	Structural	3.0	3.0	2.0	2.5	3.0	3.0	16.5	Reliability Analysis
Butterfly Valves	Structural	1.5	2.0	3.0	2.0	1.5	3.0	13.0	Reliability Analysis
Dam Tainter Gates	Structural	3.0	3.0	3.0	3.0	3.0	3.0	18.0	Reliability Analysis
Vertical Lift Gates	Structural	1.0	3.0	3.0	1.5	1.5	3.0	13.0	Reliability Analysis
Roller Gates	Structural	1.0	3.0	3.0	1.0	2.0	3.0	13.0	Reliability Analysis
Boat-Operated Wicket Gates	Structural	1.0	1.0	1.0	1.0	3.0	1.0	8.0	Screened Out
Miter Gate Anchorage	Structural	3.0	3.0	2.0	1.0	3.0	2.0	14.0	Reliability Analysis
Tainter Gate Anchorage	Structural	3.0	2.0	2.0	1.0	3.0	2.0	13.0	Reliability Analysis
Vertical Lift Gate Anchorage	Structural	1.0	2.0	2.0	1.0	1.5	2.0	9.5	Screened Out
Roller Gate Anchorage	Structural	1.0	2.0	2.0	1.0	2.0	2.0	10.0	Screened Out
Reverse Tainter Anchorage	Structural	3.0	3.0	2.0	2.0	3.0	2.0	16.0	Reliability Analysis
Butterfly Valve Anchorage	Structural	1.5	2.0	2.0	1.0	1.5	2.0	10.0	Screened Out
Service Bridge Girders	Structural	3.0	2.0	2.0	2.0	1.0	1.0	11.0	Screened Out
Service Bridge Bearing Seats	Structural	3.0	1.0	1.0	1.0	1.0	2.0	9.0	Screened Out
Stilling Basins	Structural	3.0	2.0	2.0	1.0	1.0	2.0	11.0	Screened Out
Emergency Bulkheads	Structural	3.0	1.0	2.0	2.0	1.0	1.0	10.0	Screened Out
Culvert Bulkheads	Structural	3.0	1.0	2.0	1.0	1.0	1.0	9.0	Screened Out
Intake Screens	Structural	3.0	1.0	1.0	1.0	1.0	2.0	9.0	Screened Out
Miter/Quoin Blocks	Structural	3.0	1.0	1.0	1.0	1.0	2.0	9.0	Screened Out
Bulkhead Crane (Structural)	Structural	3.0	1.0	2.0	2.0	1.0	1.0	10.0	Screened Out
Maintenance Bulkheads	Structural	3.0	1.0	2.0	1.0	1.0	1.0	9.0	Screened Out
Tainter Gate Cable Anchorage	Structural	3.0	2.0	1.0	1.0	2.0	1.0	10.0	Screened Out
Service Bridge Bearing Memb.	Structural	3.0	1.0	1.0	1.0	1.0	1.0	8.0	Screened Out
Bulkhead Crane Lifting Beam	Structural	3.0	1.0	2.0	1.0	1.0	1.0	9.0	Screened Out
Poiree Dam	Structural	1.0	2.0	2.0	1.0	1.0	2.0	9.0	Screened Out
Floating Approach Walls	Structural	1.0	2.0	3.0	1.0	2.0	2.0	11.0	Screened Out
Chamber Monolith Stability	Structural	3.0	3.0	3.0	3.0	3.0	1.0	16.0	Reliability Analysis
Miter Gate Monolith Stability	Structural	3.0	3.0	3.0	3.0	3.0	1.0	16.0	Reliability Analysis
Concrete Horizontal Surfaces	Structural	3.0	1.0	3.0	2.0	1.0	2.0	12.0	Screened Out
Type of Component	**Engineering Discipline**	**System Number**	**Site Specific Consequence**	**Site Specific Cost**	**System Cost**	**System Consequence**	**Likelihood of Problems**	**Overall Ranking**	**Phase 2 Screening Results**
Guide/Guardwall Stability	Structural	3.0	2.0	3.0	3.0	2.0	2.0	15.0	Reliability Analysis
Fixed Weir Stability	Structural	2.0	3.0	3.0	2.0	3.0	2.0	15.0	Reliability Analysis
Sheet Pile Cellular Structures	Structural	3.0	2.0	3.0	3.0	2.0	2.0	15.0	Reliability Analysis
Pile Founded Structure Stability	Structural	2.0	1.0	3.0	2.0	1.0	1.0	10.0	Screened Out
Dam Pier Stability	Structural	3.0	3.0	3.0	3.0	3.0	1.0	16.0	Reliability Analysis
Mass Concrete	Structural	1.0	2.0	2.0	3.0	3.0	1.0	12.0	Screened Out
Overflow Spillway Stability	Structural	2.0	2.0	2.0	2.0	2.0	1.0	11.0	Screened Out
Miter Gate Sill Stability	Structural	3.0	3.0	2.0	2.0	3.0	1.0	14.0	Reliability Analysis
Dam Gate Sill Stability	Structural	3.0	3.0	2.0	2.0	3.0	1.0	14.0	Reliability Analysis
Retaining Wall Stability	Structural	1.0	1.0	2.0	1.0	1.0	1.0	7.0	Screened Out
Underseepage Control	Geotechnical	1.0	2.0	2.0	1.0	1.0	1.0	8.0	Screened Out
Erosion Control	Geotechnical	3.0	1.7	1.7	1.3	1.7	2.0	11.4	Screened Out
Slope Stability	Geotechnical	3.0	1.3	1.0	1.0	1.0	1.0	8.3	Screened Out
Riprap	Hydraulics	3.0	2.0	1.0	1.5	1.5	1.5	10.5	Screened Out
Navigation Channel Conditions	Hydraulics	3.0	2.0	1.3	2.0	2.3	2.0	12.6	Screened Out
Approach Conditions	Hydraulics	3.0	2.3	1.7	2.0	2.3	1.3	12.6	Screened Out
Dikes	Hydraulics	1.5	1.0	1.0	1.0	1.0	1.0	6.5	Screened Out
Tow Haulage Unit	Mech./Elec.	1.0	2.0	2.0	1.0	1.0	2.5	9.5	Screened Out
Bulkhead Crane Machinery	Mech./Elec.	2.7	1.3	2.3	2.0	1.0	2.3	11.6	Screened Out
Hydraulic Power System	Mech./Elec.	3.0	2.3	2.7	2.3	2.0	2.0	14.3	Reliability Analysis
Fire Protection Equipment	Mech./Elec.	1.3	1.0	1.3	1.0	1.0	1.3	6.9	Screened Out
Compressed Air System	Mech./Elec.	3.0	1.3	1.0	1.0	1.3	2.0	9.6	Screened Out
Lighting	Mech./Elec.	3.0	1.7	1.7	1.3	1.3	1.3	10.3	Screened Out
Emergency Generator	Mech./Elec.	3.0	2.3	1.3	1.0	1.7	2.3	11.6	Screened Out
Motor Control Center	Mech./Elec.	3.0	2.3	1.7	1.3	2.3	1.3	11.9	Screened Out
Power and Control Equipment	Mech./Elec.	3.0	2.3	1.7	1.7	2.3	2.0	13.0	Reliability Analysis
Dam Gages	Mech./Elec.	2.0	1.0	1.0	1.0	1.0	2.0	8.0	Screened Out
Intercom System	Mech./Elec.	3.0	1.0	1.0	1.0	1.0	1.0	8.0	Screened Out
Traffic Signal System/Lighting	Mech./Elec.	3.0	2.3	1.0	1.0	2.3	1.3	10.9	Screened Out
							Total Number of Components Requiring Further Analysis -->		20

Table ED 5-2. Original Phase 2 Screening Results

In addition, the dam components were not modeled using reliability analysis as part of the ORMSS SIP. However, some sophisticated finite element analysis models of instrumented tainter gates on two Louisville District projects (J.T. Myers and Markland), which was partially funded by the ORMSS, indicated that these type of dam gates are both highly redundant and also operate primarily

under compressive stress loads. Therefore, significant reliability issues for the vast majority of dam gates on the Ohio River are not anticipated during the critical part of the study period, which is about the first 30 years or so. In addition, the dam roller gates at R.C. Byrd were recently replaced as part of major rehabilitation for that project. Some investment cost is included to upgrade the dam in the later portion of the study period, but it does not influence lock chamber performance and its cost will not be a significant part of the overall economic analysis because it will be late in the study period and the economic analysis puts future investments in present worth values. The only Ohio River project with anticipated needs to rehab of the dam gates early in the study period is at Emsworth Locks and Dam. As part of a separate major rehabilitation evaluation, a reliability analysis and subsequent economic analysis was done for the dam at Emsworth. This repair is currently under way and for the purposes of this study, it is assumed that the major rehabilitation of the Emsworth Dam will be completed within the next few years.

There are some anticipated investment needs during the study period associated with both the mechanical and electrical systems of the dams, but time and schedule did not allow reliability modeling for these components. These systems typically would not affect navigation performance anyways as part of any event tree consequences. Therefore, some future investments to upgrade mechanical and electrical systems are included in both the With Project and Without Project conditions based upon the age of the structure. These were timed by engineering judgment and placed in the cost schedules for each site.

Currently, there is no known stability issues associated with dam piers or fixed weirs for Ohio River dams. In support of this position, the lock wall monolith reliability models indicated no anticipated stability problems except for a few anchored monoliths at a couple of Upper Ohio projects. The reason there were no lock wall "failures" in the reliability analysis is because of the original safety factors included in the design of the structures. Since the overall condition of these type structures does not change significantly with time, these remain reliable throughout the study period. Due to the lock stability results and the fact there we no know dam pier/weir stability problems, the engineering team agreed that reliability models for dam stability were not warranted as part of the ORMSS.

There is one additional concern on going for several Ohio River dams and that relates to scouring of the stilling basin structure below the dewatering slots. This is a major issue at several Ohio River dams on the lower portion of the river (J.T. Myers, Newburgh, Cannelton, and Markland). A major rehab evaluation associated with the scouring of the stilling basin slabs at J.T. Myers is on-going and scheduled for submission to HQ in FY06. The preliminary results of that study indicate that roughly $30 million or so will be required to procure the necessary equipment and make necessary repairs. The optimal timing of this repair is to be determined as part of the major rehab study, but it is safe to assume it will be required before 2015. For the purposes of ORMSS, this cost will be embedded into both the With and Without Project for fixes to the dam. The same type of repair will be assumed at the other locations as noted with probable time frames for repair.

In the end, probabilistic models were developed for a total of 13 different components based upon the original rating system and the further screening as a result of budget and schedule effects. The components listed below represent the final list of major lock infrastructure modeled through probabilistic means to incorporate into the overall economic analysis. For reference below, EDM is representative of the three upper Ohio projects Emsworth, Dashields, and Montgomery.

Final List of Components for Reliability Models

1. Horizontally-Framed Miter Gates
2. Vertically-Framed Miter Gates
3. Horizontally-Framed Reverse Tainter Gate Culvert Valves

4. Vertically-Framed Reverse Tainter Gate Culvert Valves
5. Mass Concrete Degradation (EDM Only)
6. Lock Chamber Monolith Stability
    a. Unanchored Monoliths
    b. Anchored Monoliths (EDM Only)
7. Miter Gate Monolith Stability
    a. Unanchored Miter Gate Monoliths
    b. Anchored Miter Gate Monoliths (EDM Only)
8. Guard/Guide Approach Wall Stability
    a. Gravity Structures
    b. Pile-Founded Structures
9. Miter Gate Sill Stability
    a. Unanchored Miter Gate Sills
    b. Anchored Miter Gate Sills (EDM Only)
10. Hydraulic Power System (Mechanical)
11. Culvert Valve Machinery
12. Miter Gate Machinery
13. Power and Control Equipment (Electrical)

5.1.2 Types of Reliability Models

The reliability models developed for the final list of components can be separated into two general categories: non-time dependent and time dependent models. The non-time dependent models are assumed not to deteriorate significantly over time, whereas, the time dependent models degrade in reliability over time.

Time Dependent Reliability Models

Twelve of the final components were considered time dependent. These components degrade in reliability with time due to their cyclic use and associated age. The components considered time dependent are the miter gates (both horizontal and vertical), culvert valves (both horizontal and vertical), mass concrete degradation, anchored lock wall stability, anchored miter gate sill stability, anchored miter gate monolith stability, hydraulic power system, culvert valve machinery, miter gate machinery, and power and control equipment. With the miter gates and culvert valves, these structures are steel structures that are subject to fatigue and corrosion, thus, causing a decrease in reliability over time. The fatigue of the miter gate and culvert valves is a function of the number of historical load cycles that the structure has undergone over time, as well as those projected in the future. For the mechanical and electrical components, the time reliability models are a function of the number of operating cycles, along with the component's age. For the anchored walls and sills, these structures are time dependent because the anchors are subjected to fatigue and corrosion. The mass concrete degradation is an issue at EDM only. The reliability of the concrete at these projects is decreasing with time due to the several factors. This is better described in Section 5.2.8. Most importantly, hazard functions are developed for time dependent components. The hazard function is defined as the probability of unsatisfactory performance in a given year assuming it has survived up to that year, a truly time dependent analysis.

Non-Time Dependent Reliability Models

The non-time dependent components were all the unanchored gravity structures: chamber monolith stability, miter gate monolith stability, guide/guard wall stability, and miter gate sill stability. The reliability of the gravity structures at the Ohio River projects has not deteriorated over time to the point that the stability of the structure is in question. Also, since the team is only looking at normal operating loads (normal and maintenance load cases), there is not an issue of return periods or extreme loads for cases such as earthquakes or excessive barge impact forces. Therefore, the models are assumed to have the same reliability over time. This is consistent with guidance, as provided by HQUSACE for gravity structures. For these components, the probability of unsatisfactory performance is computed and assumed to be the same for every year in study period.

5.1.3 Integration of Engineering Reliability in Economic Modeling

The annual probabilities of unsatisfactory performance for each component are only one of the inputs that the engineering team must supply to the economists for their analysis. The engineering team is also required to provide the economists with an event tree for each component depicting several repair options given the limit state of the component.

For all of the components for which reliability analysis was completed, the engineering team supplied probabilities of unsatisfactory performance for non-time dependent components and hazard rates for time dependent components. These values are provided for every year between 2005 and 2070. As noted previously for non-time dependent components, the values are the same in each year. However, for time dependent components, each year could have a different value.

The engineering team also provides consequence event trees for each component to the economists. These event trees supply the economists with information regarding potential repair options if a component were to perform unsatisfactorily. Since the engineering team is only supplying probabilities associated with major types of unsatisfactory performance, the event tree reflects potential repairs for major events. Along with the repair scenarios, the engineering team also supplies the physical repair cost and required chamber closure time associated with each repair option, along with the effect the repair had on the component with regard to future reliability. Event trees vary for each individual component, however, the general format of each one is supplied in Figure ED 5-2. See the individual component sections for specific event trees.

The first branch of the event tree is the annual probability of unsatisfactory performance (PUP) for the component for any particular year between 2005 and 2070, the study period. The second branch is the level of repair associated with the annual PUP. In general, this branch will have a two or three legs whose total percentage must equal 100 percent. The percentages were selected by the team of engineers that developed the model, in consultation with Operations personnel experienced with the repair techniques for the particular component. The third branch is the cost to repair the component for each level or repair, along with the amount of time in days the chamber is closed to navigation. These costs and closures again were developed by the engineering team that developed the model, along with consultation with appropriate Operations personnel. The last branch is the upgrade to future reliability based upon the repair. This effect is based upon engineering judgment on the team that developed the model.

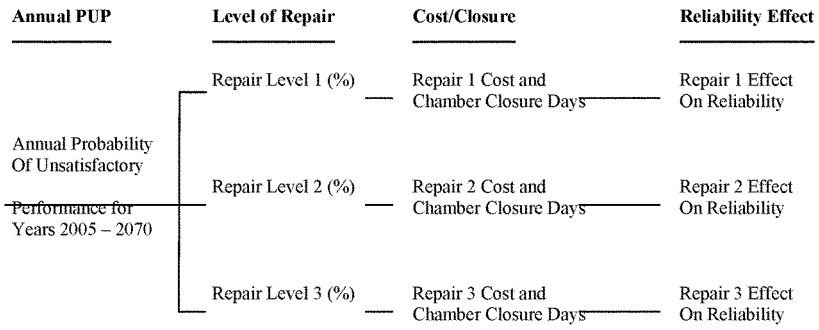

Figure ED 5-2. Typical Event Tree for Reliability Models

Engineering Reliability Analysis Sections

The overall amount of engineering data calculated and used for this report can be overwhelming for those not very familiar with process and details of the analysis. For just the engineering reliability analysis, time dependent hazard rates had to be computed for 35 lock chambers (Olmsted and the new lock chamber at McAlpine did not require reliability analyses) with roughly 6 components per lock, and 5 traffic forecasts for each component. This equates to over 1000 sets of time dependent hazard rates computed for this analysis. An additional hundreds of other calculations for non-time dependent components were also done. Trying to sort through this data in a clear and concise manner is not easy even for those doing the computations. Therefore, in order to clearly explain the modeling process for each individual component, it was thought that the best way to thoroughly explain the process was to go through each model at one of the Ohio River sites for a single traffic scenario. This would be done for each component modeled. Because different projects were used for calibration of different models, the narrative will detail components at different projects. This should give the reader a good overview of how each component reliability analysis was developed and followed through for the entire analysis.

5.2 HORIZONTALLY-FRAMED MITER GATE RELIABILITY

Each of the horizontally-framed miter gates on the Ohio River is of similar design and construction techniques. Each is designed for a 110-ft wide chamber and is constructed of built-up, welded members. The exception to this is the upper three auxiliary chamber miter gates for EDM. These chambers are 56-ft wide and the gates are made from rolled members. Because these auxiliary miter gates at the upper three sites are not used very often, are relatively new from recent major rehabilitations, and they are constructed of rolled sections, it was decided by the team that a reliability analysis for these gates was not warranted.

5.2.1 Background

The horizontally-framed gates on the Ohio River locks were separated into four distinct groups for their reliability analyses. The first group consisted of miter gates that had floating, welded pintle design with one set of diagonals per leaf. This group included the following sites: Willow Island, Belleville, Racine, Greenup, Meldahl, Markland, and McAlpine. The global finite element model for the first group was modeled after the Markland miter gates. The second group consisted of miter gates with fixed, bolted pintle design with two sets of diagonals per leaf. These sites included the miter gates at New Cumberland, Pike Island, and Hannibal. The second group global finite element model was based upon the downstream gates at New Cumberland. The third group consisted of miter gates with a fixed, bolted pintle design with one set of diagonals per leaf. These sites included Cannelton, Newburgh, J.T. Myers, Smithland, R.C. Byrd, and Olmsted. The basic, global finite element for group three was modeled based upon the Cannelton miter gates. The final group is the auxiliary chamber miter gates at Emsworth, Dashields, and Montgomery. As discussed previously, no reliability modeling was required for the group four miter gates. Refer to Figure ED 5-3 for the grouping of Ohio River horizontally-framed miter gates.

The basis for the analysis and reliability model for all horizontally-framed miter gates on the Ohio River was based upon the Markland miter gates. Markland represents the oldest project on the Ohio River that has not been rehabilitated. The gates are experiencing fatigue cracking and are nearing the end of their original design life (assumed to be 50 years). The team originally investigated traditional strength and fatigue analysis associated with the main load carrying members for bending. After initial results indicated no potential problems at Markland for the entire study period, it was decided to refocus the effort towards actual field experience at Markland. It is important to note that other miter gates on the Ohio River have experienced similar cracking patterns, but to a less extent than the current damage to Markland's gates. A brief history of the problems encountered with the Markland miter gates is described below followed by the development of the model and calibration.

5.2.2 Overview of the Miter Gate Model

Serious concern regarding the integrity of the miter gates at Markland arose during a scheduled maintenance dewatering in 1994. This dewatering was scheduled to do major maintenance for the main chamber, including jacking the miter gates and replacing the pintle, seals, etc. However, once the chamber was dewatered and the gates were inspected, severe cracking at several locations was noted. Many of the cracks were at welded connections of the main load carrying members. In particular, the heaviest cracking occurred near the pintle area on the lower girders. It was determined that the extensive cracking was fatigue-related. Since the gates had seen less than 40 years of operation at the time of the 1994 dewatering, the fatigue of the gates was considered to be an abnormal failure mode. In order to determine the cause for this type of extensive cracking, the Louisville District hired an engineering consultant specializing in nonlinear finite element modeling to help determine the cause for the early fatigue cracking. It was determined by the Louisville District and the consultant that the root cause of the early fatigue cracking was due to the original fabrication and erection when the flanges and webs were welded together and subsequent repair methods when welding was used to repair smaller cracks throughout the history of operation. Because of the large number of structural members joined together in the pintle area, the entire region is highly constrained from movements due to temperature fluctuations. When welding occurs, large stresses are developed in the members near the weld joints. As the weld joint cools, large tensile stresses (termed residual stresses) are "locked" in place because the restraints of the gate in the pintle area. The large tensile stresses then are subjected to normal operating loads due to pool fluctuations as a chamber goes between upper and lower pool. When the gate is holding back pool, compressive stresses are applied to these areas where the tensile, residual stresses are locked in, thus, causing a stress reversal during each operation. This large stress reversal,

Ohio River Main Stem Systems Study
Horizontally-Framed Miter Gate Information Sheet

									Gate Properties at Pintle Area							
	Site	Service Year	Lift (ft)	Pintle Design Base	Pintle Design Connection	Diagonals per Leaf	Number of Girders	Bottom Girder Depth	Web Thickness	Downstream Flange	Thrust Plate Thickness	x-dist. from quoin	Girder Depth at x-dist.	Flange Crack Length	Critical Crack Length	Upstream Flange
Group 1	Willow Island	1972	20	floating	welded	one	11	70"	5/8"	16 x 1	0.75" avg.	44"	38"	3.75"	23.31"	16 x 1
	Belleville	1965	22	floating	welded	one	12	70"	5/8"	16 x 1	0.75" avg.	44"	38"	3.75"	23.31"	14 x 1
	Racine	1967	22	floating	welded	one	13	70"	5/8"	18 x 1	0.875" avg.	44"	38"	4.25"	23.31"	20 x 7/8
	Greenup	1959	30	floating	welded	one	15	70"	5/8"	18 x 1	0.75" avg.	44"	38"	4.25"	23.31"	20 x 7/8
	Meldahl	1962	30	floating	welded	one	15	70"	5/8"	18 x 1	0.75" avg.	44"	38"	4.25"	23.31"	20 x 7/8
	Markland	1959	35	floating	welded	one	14	70"	5/8"	18 x 1	0.75" avg.	44"	40"	4.25"	23.31"	20 x 7/8
	McAlpine	1962	37	floating	welded	one	16	70"	5/8"	18 x 1	0.75" avg.	44"	40"	4.25"	23.31"	20 x 7/8

									Gate Properties at End of Quoin Diagonal Plate							
Group 2	N. Cumberland (u)	1959	20.5	fixed	bolted	double	8	61-3/8"	7/16"	15"x 5/8"	0"	100"	61-3/8"	7.28"	0"	15 x 1
	N. Cumberland (d)	1959	20.5	fixed	bolted	double	11	61-3/8"	3/8"	15"x 5/8"	0"	100"	61-3/8"	7.31"	0"	15 x 1
	Pike Island (u/s)	1963	21	fixed	bolted	double	9	61-3/8"	3/8"	15"x 3/4"	0"	100"	61-3/8"	7.31"	0"	15 x 1
	Pike Island (d/s)	1963	21	fixed	bolted	double	11	61-3/8"	7/16"	15"x 3/4"	0"	100"	61-3/8"	7.28"	0"	15 x 1
	Hannibal	1972	21	fixed	bolted	double	11	61-3/8"	3/8"	15"x 5/8"	0"	100"	61-3/8"	7.31"	0"	15 x 1

									Gate Properties at End of Quoin Diagonal Plate							
Group 3	Cannelton	1973	25	fixed	bolted	one	14	54"	1"	9 x 1	0"	89"	54"	19.3"	0"	18 x 2
	Newburgh	1974	16	fixed	bolted	one	12	54"	3/4"	9 x 1	0"	89"	54"	19.65"	0"	14 x1.25
	JT Myers	1972	18	fixed	bolted	one	13	54"	1"	9 x 1	0"	89"	54"	19.5"	0"	16 x 1.375
	Smithland	1979	22	fixed	bolted	one	13	54"	3/4"	9 x 1	0"	89"	54"	19.73"	0"	12 x 1
	RC Byrd	1993	23	fixed	bolted	one	12	70"	3/4"	12 x 1/2	0"	89"	70"	26.25"	0"	8 x 3/4
	Olmsted	2006	15	fixed	bolted	one	11	54"								

Grp 4	Emsworth Aux.	1982	18	fixed	bolted	one	15	24"	1/2"	7"x 7/8"						
	Dashields Aux.	1984	10	fixed	bolted	one	16	24"	1/2"	7"x 7/8"						
	Montgomery Aux.	1984	18	fixed	bolted	one	14	24"	1/2"	12-3/4"x 3/4"						

Figure ED 5-3. Ohio River Horizontally-Framed Miter Gate Data Sheet.

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coupled with the historical number of load cycles, has caused the fatigue-related cracking on these of gates. Figures ED 5-4 through ED 5-8 shows several photos from the 1994 dewatering.

Figure ED 5-4 depicts the widespread cracking present in the main chamber miter gates. The white arrows in the photo show areas where large cracks were found and in need of immediate repair. Note most of the cracking on this leaf is occurred where the vertical stiffeners were welded to the horizontal girders. Cracks initiated at that connection and grew through the girder flange.

Figure ED 5-5 shows repair technique on one of the miter gate leafs. Repair consisted of gouging out the entire length of the weld and re-welding material back together. Note cracking on this leaf initiates at corners of small diagonal plates and girder/stiffener flanges and then proceeds through flange. Additionally, note extensive length of cracks.

Figure ED 5-6 depicts cracking also prevalent near pintle region where diagonal plate is welded to the gate. White arrows show positions of extensive cracking. Note new flange for lower girder for this leaf. This was added due to damage to lower girder flange on this girder.

Figure ED 5-7 shows main chamber miter gate damage to the lower girder downstream flange. Note damage to lower girder flange plate due to buckling of the web. The buckling of the web helped cause the connection between the web and flange plate to separate as shown in Figure ED 5-8.

Figure ED 5-8 is a photograph that shows a close-up of the damage to the flange plate looking from "inside" the girder towards the downstream flange plate. Note the separation of the flange plate from the web of the girder. coupled with the historical number of load cycles, has caused the fatigue-related cracking on these of gates. Figures ED 5-4 through ED 5-8 shows several photos from the 1994 dewatering.

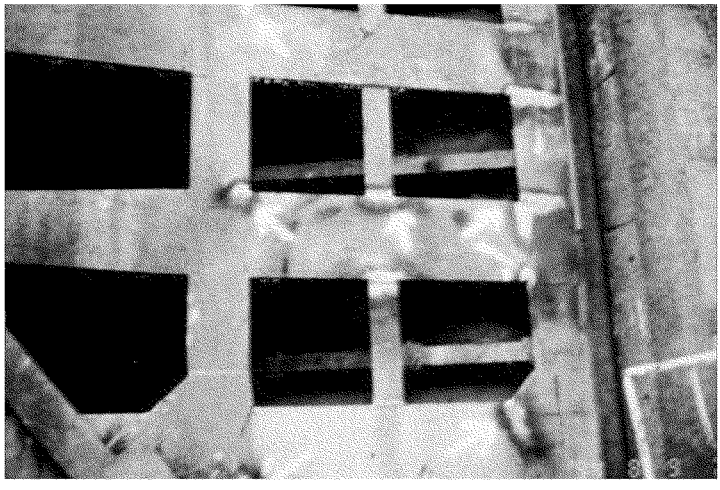


Figure ED 5-4. Main Chamber Miter Gate Cracking Above Pintle

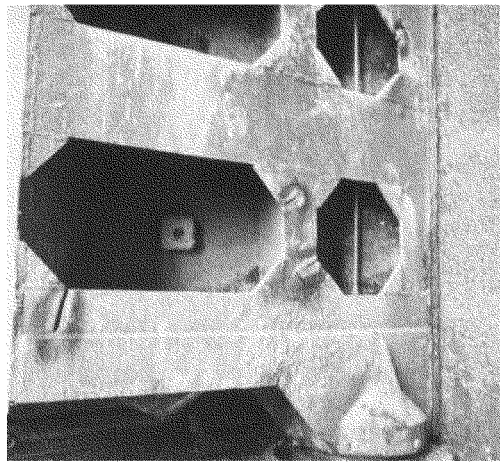


Figure ED 5-5. Main Chamber Miter Gate Crack Repair in Pintle Region

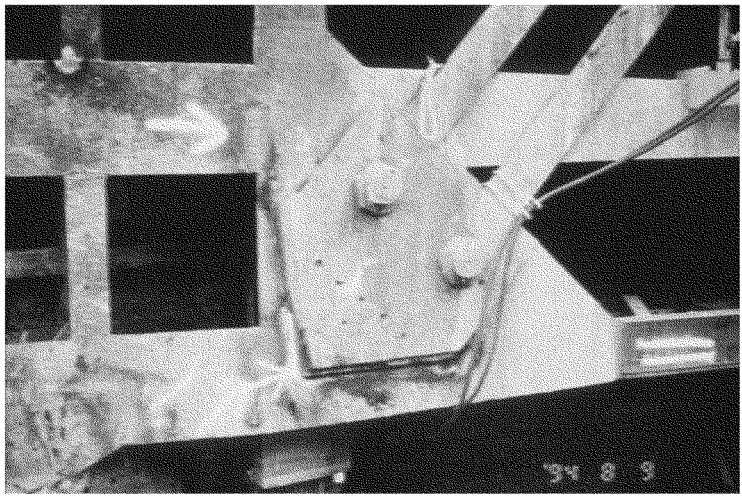


Figure ED 5-6. Main Chamber Miter Gate Cracking Near Diagonal Plate

Figure ED 5-7. Miter Gate Damage to Lower Girder Downstream Flange

Figure ED 5-8. Miter Gate Damage to Lower Girder Downstream Flange

5.2.3 Finite Element Modeling of Miter Gates and Calibration

The fatigue cracking problem at welded flange connections on the Markland miter gates was summarized in previous sections. To evaluate the fatigue cracking problem from a reliability standpoint, the initiation and growth of the fatigue cracks must be characterized in terms of the variability of the parameters that control the fatigue cracking. The development of such a reliability model has three major components; 1) to determine the characteristics and variability of the initiation of fatigue cracks, 2) to establish the rate of crack growth and its variability, and 3) determine the limit state of the gate, which is defined as the extent of fatigue crack growth that will compromise the integrity of the gate.

The fatigue crack initiation and growth is primarily influenced by the residual stresses that develop during the welding of the girder flange and vertical stiffener flange. Large tensile residual stresses can develop in the flanges around the welded area due to constraints against thermal expansion (and contraction) during the welding process. The arch action of the gate under hydrostatic operating loads develops compressive stress in the flanges in the pintle region. These compressive operating loads, which are exasperated by the geometric re-entrant corner at the welded flange connection and the usually rough surface at the weld bead coupled with residual stress field, produce large stress cycles that initiate fatigue cracks.

A numerical study using finite element modeling was conducted to evaluate the cracking at welded flange connections.[1] As depicted in Figure ED 5-9, this study used global modeling of the gate leaf to define the range of compressive loads that develop in the girder flanges near the welded connections. Normal operating conditions as well as pintle wear and gate misalignment were considered. Detailed local models of the flange connection were used to establish the residual stress distributions by numerically simulating the weld process. This methodology was benchmarked against test data from the literature where stress magnitudes and distributions were measured around a weld on A36 steel as illustrated in Figure ED 5-10. Once the residual stress field was established in the local model, the flange loads were applied consistent with the global operational loads. The stress range for a cycle of operation was determined from a gate open condition, which includes gravity load, diagonal prestress, and residual stresses, to a gate closed condition that adds the operational loads. This stress range is then used to evaluate the number of cycles for crack initiation based on the American Society of Mechanical Engineers' design fatigue curve for carbon steel.[2] This calculation for fatigue crack initiation correlated very well with the observed cracking in the Markland miter gates during the 1994 and 1996 dewatering inspections.

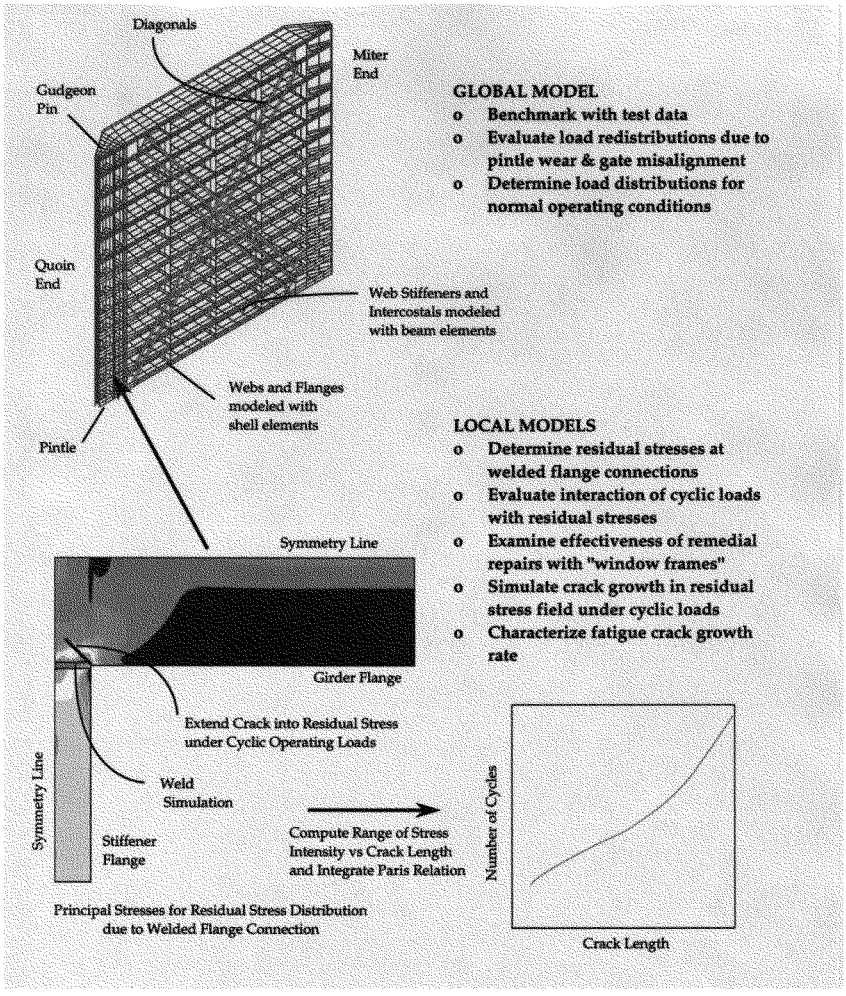


Figure ED 5-9. Global Finite Element Model of Markland Miter Gates

The next step was to develop a method for evaluating the rate of fatigue crack growth. Typically, the linear elastic fracture mechanics (LEFM) based formulas for stress intensity as a function of stress level and crack length of the form,

$$K = Q\sigma\sqrt{\Pi a}$$

are used to develop a relationship for the change in stress intensity versus crack length. This stress intensity relationship is then used with the Paris relation,

$$= \quad \triangle$$

Where C and n are material parameters (with variability) for integration to find the crack growth rate. This method is illustrated in the Corps of Engineers' procedure for structural inspection and evaluation of welded lock gates.[3] However, these LEFM formulas are developed based on uniform far field stresses and, most often, Mode I crack growth. In this case, the driving stress for crack growth is the tensile residual stress distribution at the crack rather than the remote compressive flange stress. Moreover, these residual stresses change as the crack extends. Thus, another method for determining the rate of crack growth was required. The method that was developed in the Markland study was to extend a crack within the residual stress field in the local finite element model and compute the resulting stress intensity value under gate open and closed conditions. This was accomplished using the J-integral method to calculate the energy release rate for an increment of crack extension. The stress intensity value is computed from the energy release rate using LEFM assumptions. This energy based method also accounts for contributions to crack growth from all modes of crack extension. The Mode II or shear contribution is considered significant in this situation. Thus, a relation for stress intensity versus crack length was constructed by numerically extending a crack from the corner of the welded flange connection in the local model for gate open and closed conditions. The range of stress intensity versus crack length was then used to integrate the Paris relation to determine the crack growth rate of the fatigue cracks. As illustrated in Figure ED 5-11, this calculated crack growth rate correlated very well with the observed crack lengths in the Markland gates during the 1994 and 1996 dewaterings.

The development of the reliability model for horizontally-framed miter gates is based upon the above methodology. The intent of the model is to characterize the variability of the fatigue crack initiation and growth. The engineering team evaluated the importance of the parameters that influence fatigue cracking to establish the variables for characterization. A matrix of calculations is then performed with variations of these variables to develop relationships on the fatigue crack initiation and growth. The residual stress at a welded connection is influenced by many parameters, such as type of weld, number of passes, yield strength, strain hardening characteristics of the base metal and weld metal, and the degree of was not necessary to develop a reasonable residual stress distribution around the welded areas that govern the extended growth of fatigue cracks. Based on this work, the engineering team identified the material yield stress and the degree of constraint as the important random variables for developing the residual stress distribution at a welded connection. The temperature dependence and strain hardening variations are tied to the variation in yield stress. The degree of constraint is incorporated in the evaluation by considering three different types of welded connections. Thus, local models are developed for 1) the stiffener flange to girder flange connection, 2) the pintle casting to lower girder connection, and 3) the diagonal anchor plate to girder flange connection. These connections represented areas of the miter gate where fatigue cracking has been observed and are considered likely to have serious reliability consequences for extended cracking. constraint during welding. The Markland miter gates demonstrated that modeling the weld process

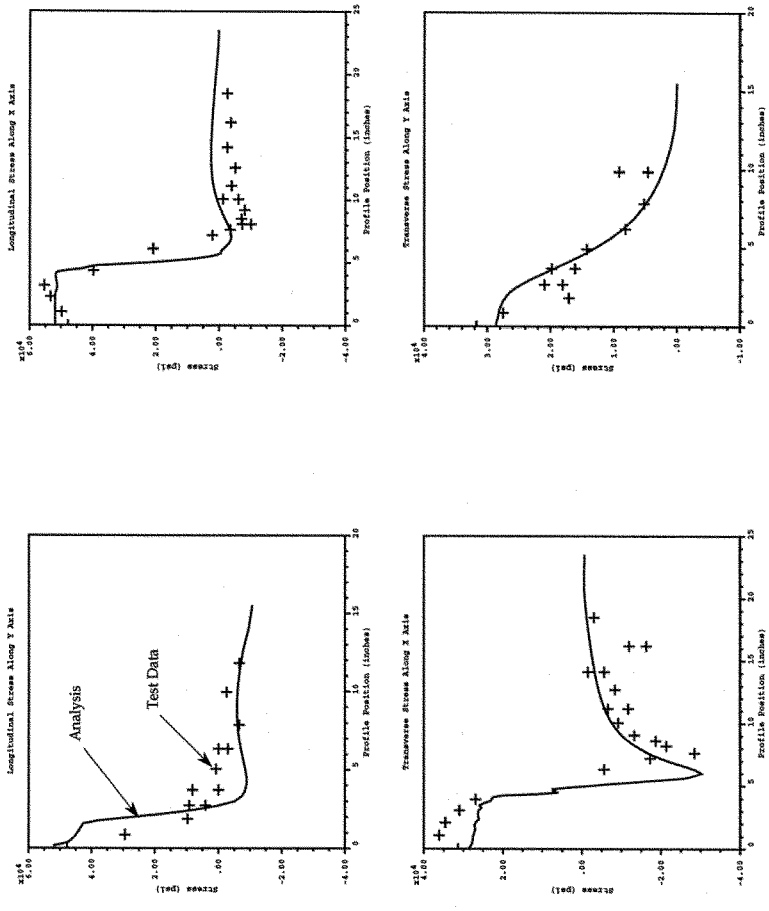


Figure ED 5-10. Stress Distribution Around Welds on A36 Steel.

The fatigue cracking is also governed by the compressive side of the stress cycle, so that the reliability model must be characterized in terms of operating stress on the connection, typically the girder flange stress, which can be related to the head variations. Finally, the crack growth is defined by the material constants in the Paris relation, and the material coefficient is also defined as a random variable. Thus, for each local connection model, analyses are conducted with material variation in yield stress to develop the resulting variations in residual stress distributions. Then variations of flange stress are applied to each variation of residual stress to develop combinations of stress ranges. That is, curves of peak tensile residual stress versus yield stress are constructed along with curves of peak

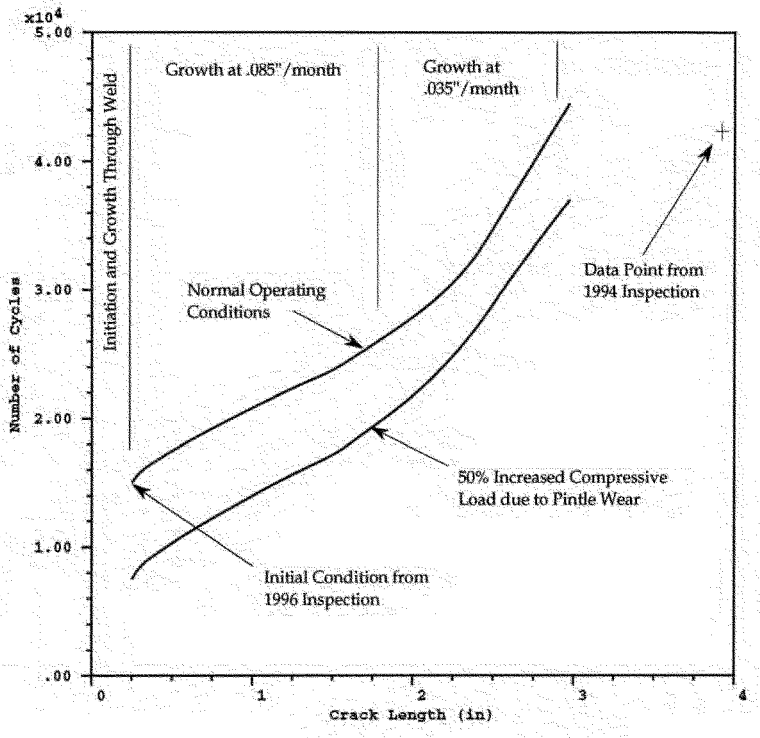


Figure ED 5-11. Graph Depicting Crack Growth Rate vs. Operating Cycles

compressive stress acting on the residual stress field vs. nominal flange stress. These relations are then fit with equations for defining the reliability model. The variation in crack initiation is characterized by evaluating the variation in cyclic stress range for given values of the random variables and using the ASME fatigue design curve to define the allowable number of cycles for crack initiation. A variation on the fatigue design curve was not considered necessary since this curve has been adjusted for material variation and because the results using the above method benchmarked very well with the observed crack initiation on the Markland gate.

The variability of the fatigue crack growth is developed in a similar manner. Cracks are extended in the variations of residual stress distributions for different variations of operating flange stresses to develop families of curves for stress intensity versus crack length. These variations are then used to integrate the Paris equation with variations in the material constant to develop families of curves for crack length vs. number of cycles for the variations in yield stress, flange stress, and fatigue rate coefficient. An equation is then fit to this data and the incremental form used to return an increment in crack extension for a given number of cycles and current values of the random variables.

5.2.4 Limit State of the Miter Gates

The methods and procedures used to characterize the initiation and growth of fatigue cracks at welded connections was described in the previous section. The next component in the reliability model is to define the limit state of the gate, which is the extent of fatigue cracking that will compromise the integrity of the gate. As the fatigue cracks grow into the flanges, the effective area for compression loads is reduced, and the effectiveness of the flange in preventing buckling of the webs is reduced. In the quoin region where compressive loads are high, buckling of the girder webs could lead to progressive failure of the gate. The limit state of the gate is thus defined by considering the degradation on the buckling characteristics for the growth of fatigue cracks. A baseline for the margin against buckling under normal operating loads is first established for the undamaged gate. Fatigue cracks are then extended in the global model by disconnecting elements in the mesh. Buckling calculations are conducted for increasing levels of damage until a criteria defining the limit state is reached.

For these redundant structures, local buckling can be tolerated without seriously compromising the gate integrity. Local buckling of girder webs in diaphragm bays is known to occur without serious consequences. In the buckling calculations, an eigenmode method is used to find a factor (eigenvalue) on the operating loads such that the associated buckling shape (eigenvector) has a zero stiffness. A sequence of buckling shapes and associated load factors is determined. A criteria must be established for the buckling characteristics that define a limit state for the gate. The criteria defined for this study is that any of the following conditions warrants a limit state that compromises the integrity of the gate;

(1) A buckling mode that extends over more than 1 girder (global buckling),
(2) A buckling mode that extends over more than ½ of a girder,
(3) Whenever the lowest buckling mode has a load factor less than 1.1.

Since the buckling characteristics are highly dependent on initial imperfections and the buckling calculations consider only nominal (perfect) geometries, the last criteria for a 10% safety factor is deemed appropriate. The buckling calculations also do not consider the progressive nature of buckling in that each calculated buckling mode is independent of the previous modes occurring with smaller load factors.

For each type of connection, the limit states are determined by progressively incorporating fatigue cracking damage into the global model and evaluating the buckling characteristics against the above criteria. Table ED 5-3 summarizes the levels of damage found to constitute limit states for the gate under fatigue cracking damage. The level of damage needed for failure due to cracking at the pintle casting connection and for the diagonal anchor plate to girder flange connection were found to be much greater than for the stiffener flange to girder flange connection in the pintle region. In addition, the crack initiation phase is typically longer and the growth rate slower due to lower compressive working stresses at these connections. The residual stresses are also lower because there is usually less constraint at these connections during the welding of the connection. Therefore, it was found and concluded by the engineering team that the stiffener flange to girder flange connection is the controlling case for reliability of the miter gates for Group 1. It was determined that the cracking at the girder flange to the diagonal anchor plate was the controlling case for the Group 3 miter gates, which includes J.T. Myers. Figure ED 5-12 illustrates the buckling mode for the undamaged Markland gate.

Figure ED 5-13 illustrates the level of damage needed to compromise the integrity of the gate due to buckling of the girder webs in quoin region. This level of damage basically needs to be such that the horizontal flanges are rendered completely ineffective in supporting the webs on the bottom two girders.

The first scenario investigated was that the cracks initiating in the girder flange at the corner of the connection would grow through the flange width to reach the web. Cracking would need to initiate and proceed from both the top and bottom of the flange and at the connections on both ends of the span along the web between stiffeners. However, as this type cracking develops, the global model showed that the resulting load redistribution in the gate would inhibit the continued crack growth at two of the opposite corners of the flange connections. The detailed local models also indicated that while the crack starts along a 45° angle from the corner of the connection, the residual stress field would cause the crack to turn horizontal toward the stiffener web. This leads to the conclusion that the fatigue crack would turn and grow into the secondary residual stress field of the welded connection joining the stiffener web on the underside of the girder flange. Because of the continuous tensile residual stress along the flange to girder connection, the fatigue crack is likely to have a fairly constant growth rate during this mode for very long crack lengths. As the cracking extends toward the girder web along the stiffener to girder flange connection, the large compressive loads in the girder will then cause the cracking to continue along the girder web to girder flange connection. This type of cracking at the girder web to girder flange connection has been observed in the Markland gate in the diaphragm bay next to the quoin region. This cracking will completely separate the flange from the web leading to buckling of the web in the highly compressive load region. Because the local models of the welded flange connection only considered the growth of the fatigue crack in the girder flange, an additional local model was developed to define the growth rate of the crack along the flange to web connection. This model required three-dimensional finite element modeling because of the geometry involved.

Type of Connection	Damage Required for Gate Instability
Girder Flange to Stiffener Flange in Quoin Region	Separation of Girder Flange on Bottom 2 girders
Girder Flange to Diagonal Anchor Plates at Quoin Region	Cracking through Flanges and into girder web for 1/8 of web depth on bottom 2 girders
Welded Pintle to Bottom Girder	Extensive Cracking Required. Will not Govern Fatigue Life

Table ED 5-3. Levels of Damage for Limit State of Markland Miter Gate

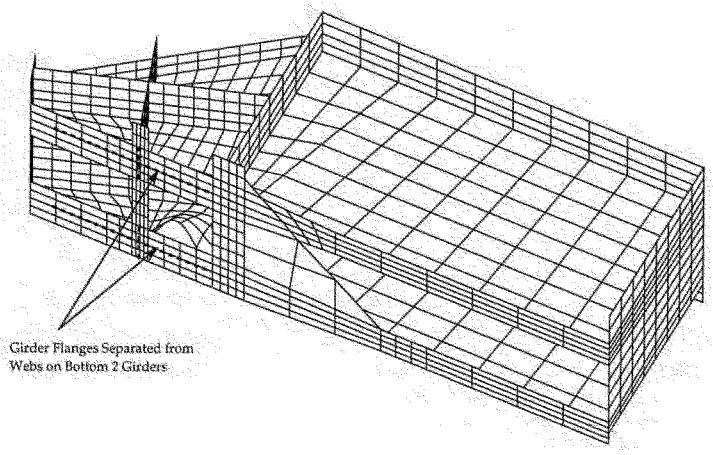


Figure ED 5-12. Buckling Damage of Markland Gate from Finite Element Model

5.2.5 Baseline Condition for Horizontally-Framed Miter Gates

The baseline condition represents the current Louisville District Operations personnel's method of operation concerning Ohio River lock maintenance. In general, the main chambers are dewatered at 5-year intervals for inspection and routine maintenance on the entire chamber. These dewaterings are usually 10 to 15 days in duration and repair work consists of inspection of the miter gate, along with minor repairs. Additionally, an overall inspection of the chamber is completed including machinery and valves. However, every 15 years (or the third dewatering of the 5-year cycle) is for significantly more maintenance to the chamber. At this dewatering, the miter gates are jacked in place and pintles, seals, and quoin/miter blocks are re-worked or replaced. Other chamber work also takes place during this dewatering such as culvert valve repair, gate and valve machinery work, along with clearing the culvert of debris build-up. These larger dewaterings usually take anywhere from 30 to 45 days. Intermittent dewaterings 15 to 30 days in duration are also required for non-miter gate work to properly maintain the lock chamber. For a more detailed description of maintenance scenarios and their effect on lock chamber closures on a district/lock project basis, please refer to Section 6 of this appendix.

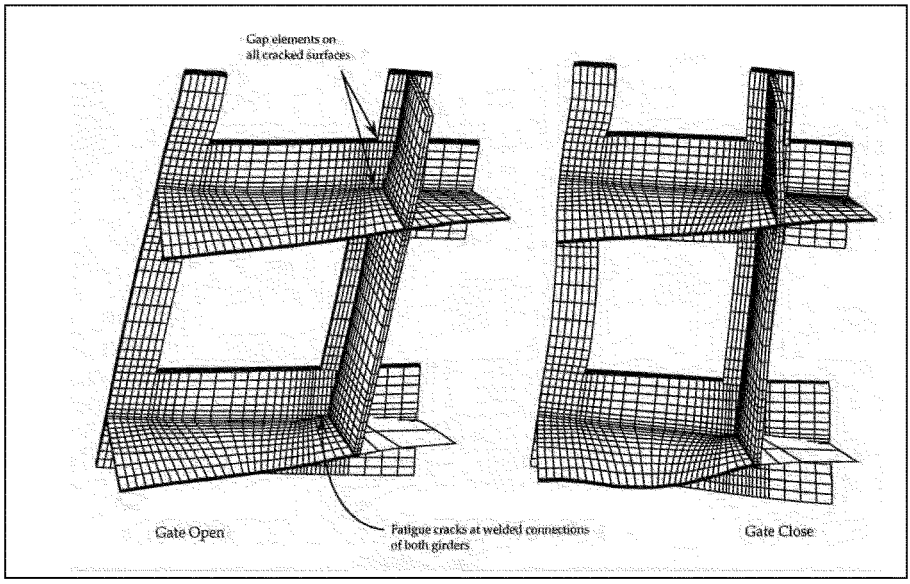


Figure ED 5-13. Buckling Damage Required for Major Failure of Miter Gates

Because the work involved with the normal maintenance schedule is generally for repair/replacement of maintenance items (seals, pintles, etc.), it is assumed that normal maintenance does not upgrade the overall reliability of the gate from a fatigue and corrosion standpoint. Therefore, for the reliability assessment, the baseline condition is considered a "fix-as-fails" approach.

5.2.6 Reliability Model Parameters

The reliability analysis for the horizontally-framed miter gates was developed to focus specifically on the type of cracking and problems that were occurring in the field. In order to accomplish this effort, the team focused its effort toward developing a model based upon the finite element analysis of the Markland miter gates. It was learned from developing the vertically-framed miter gate model for ORMSS that using the spread sheet on time dependent models was time consuming and often difficult to track changes and output. After initially developing a basic model with the spreadsheet, the engineering team decided to develop a Visual Basic coded model specifically for the ORMSS horizontally-framed miter gates and use Markland as the basis for the analysis. Therefore, the team coded their own model focusing on the cracking of the miter gates near the pintle and used @Risk^{TM} libraries for the Monte Carlo simulation within the reliability model. Immediately, it was determined that the coded model served the team's needs better for this component as it was easier to track changes and make calibration runs. The model was named HWELD since it was based upon the premise of crack initiation at welded connections.

5.2.7 HWELD Reliability Model Input

The following sections detail the input menus for HWELD for running a reliability analysis for a set of ORMSS horizontally-framed miter gates. A few of the sections have figures supplied with them for the Markland input values to give the reviewer a feel for inputting data into the program.

A) Lock Information. The first portion of input file is the project location, chamber, and girder that is being analyzed. For most ORMSS sites, the miter gates for both the main and auxiliary chamber gates are the same in terms of design and construction technique. However, operating cycles and age are different for the chambers and thus, each must be analyzed separately. The input menu from HWELD for the Markland miter gates is shown in Figure ED 5-14 as an example.

B) Cross-Section Properties of Miter Gate. The properties of the miter gate girder are required in order to compute the operating stresses in the area where the gate is susceptible to cracking. The required input for cross-section properties of the miter gate in HWELD is for the web/flanges, thrust plate, and overall gate geometry. The values are treated initially as constants but decrease over time in thickness dependent upon the paint life and corrosion rate. A series of input menus guide the user through the necessary property inputs for the girder properties, thrust plate properties, and finally, the overall gate geometry.

Web/Flanges – The inputs required for the upstream (u/s) and the downstream (d/s) web/flanges in HWELD are the thickness and width of the flange and the thickness and depth for the web in the quoin area. The x-distance is defined as the "section cut" from the quoin contact block to the critical point of interest where cracking of the welded connection is being considered. Since cracking for the base case (Markland) miter gates is widespread in the pintle region, the average x-distance is used for the middle diaphragm location. As an example, the HWELD web/flange property input values for the web/flanges cross-section properties for Markland are shown in Figure ED 5-15.

Thrust Plate – The HWELD inputs for the thrust plate are the width, thickness, and the distance from the downstream (d/s) flange.

Geometry – The required inputs for the geometry of the horizontally-framed miter gate are the gate height, spacing of girders, skin plate thickness, and working length. Other data is input into HWELD and is not directly used in the reliability calculations. This data is used only for information and includes items such as the gate height, length of girders, and tangent of angle that the girders are oriented.

C) Crack Parameters. The crack parameters required for the HWELD program are the initital crack length, the flange crack length, and the critical crack length. The initial crack length is set to a default value of 0.25 inches. This value is based on the results from the finite element analysis discussed in the previous section. The flange crack length is the distance from the initial crack through the flange to the web. The critical crack length is defined as the critical distance along the web and flange welds to which the limit state buckling of the thrust plate occurs.

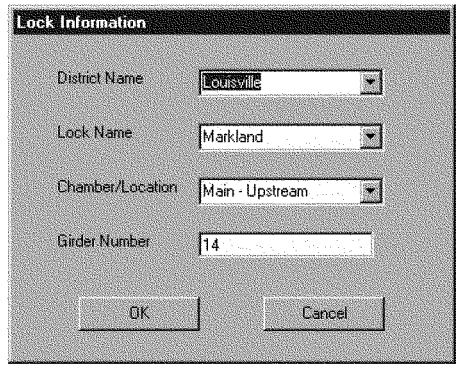


Figure ED 5-14. Lock Information Input Menu for HWELD Reliability Model

D) Head Histogram. The head histogram reflects the actual past distribution of head differential ~~for operating cycle~~s for the each set of miter gates. This distribution is based on true daily lockage cycles available from the Lock Performance Monitoring System (LPMS) combined with the true head differential for each day. This distribution is valuable in determining the fraction of annual cycles versus the expected head differential that is used for fatigue analysis. The head histograms developed by WES are based on data collected and analyzed for approximately 12 years (1984–1995, inclusive) of lock operation. The HWELD program allows the input of up to 20 different blocks for head (at specified midpoints for ranges) and fraction of cycles from the histograms. This histogram is used in HWELD to parse the input annual cycles into the defined stress range blocks and number cycles for fatigue analysis. The example head histogram input for Markland is shown in Figure ED 5-16.

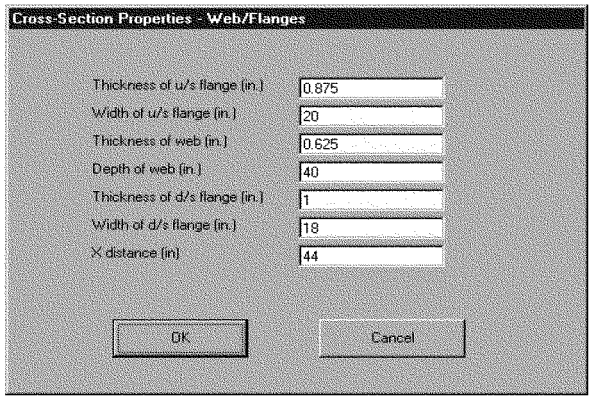


Figure ED 5-15. HWELD Web/Flange Properties Input Menu

E) Traffic Cycles. The number of operating cycles for the gates are determined for each lock based on actual and predicted future cycles for the study period. The cycle information is used in fatigue analysis incorporated into the HWELD program. The cycles are input from the start of operation to the end of the study period. Operating cycles from the origination of the each project through 1983 were determined by going through the log books to determine the number of lockages in each chamber. A ratio of lockages to operating cycles was determined and assumed to be the same in the past as well as for future projected cycles. Traffic cycles for 1984 through 2004 were determined on historical traffic using LPMS data. Future traffic projections for each of the five scenarios (Clear Skies, Modified Clear Skies, NAAQS, Utility Based, and Utility High) were provided by the ORMSS Economics Team.

F) Paint History. The painting of the miter gates can be incorporated in the reliability analysis. This directly effects the corrosion of the gate members based on the defined paint life. The input required is the specified paint life and the year in which the gates were painted. These paintings are assumed to be for the entire gate and not just spot painting of gate. If a gate is painted after the initial paint life is exceeded then corrosion is not invoked until the end of the paint life. Paint histories can be entered for up to three different years.

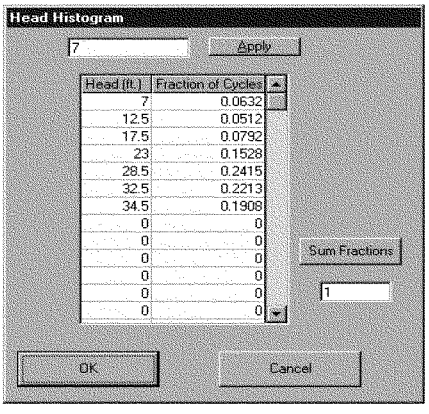


Figure ED 5-16. HWELD Head Histogram Input Menu

5.2.8 Random Variables

The random variables incorporated into the reliability analysis of the miter gates are the yield strength of the steel, corrosion rate, stress concentration factors, and misalignment/pintle wear factors. These random variables are simulated using either direct Monte Carlo simulation or a modified simulation method called Latin Hypercube. The Latin Hypercube method utilizes stratified sampling of the input distributions for quicker convergence and both methods are incorporated into the HWELD program. Pool level differential between the upper and lower pools (commonly referred to the head) is essentially a random variable because the actual histogram allows for heads in eight different ranges but the values are not chosen separately for each iteration, therefore, it represents a more accurate

measure of the pool level distribution at each project. The input distributions and statistical moments for the random variables are defined in the sections below.

A) Yield Strength. The distribution for yield strength is based on data from the published literature and previous Corps of Engineers reliability studies. The distribution is based on a truncated lognormal with a nominal yield stress of 38.88 ksi (i.e., mean yield strength times the strength ratio) and a standard deviation of 5.44. The lower limit for truncation is based on one standard deviation below the nominal (33.88 ksi) and the upper limit is based on approximately two standard deviations above the nominal (51 ksi).

B) Corrosion Rate. The distribution for corrosion rate is based on the data from the published literature and previous Corps of Engineers reliability studies. Corrosion is based on a power law that has been fit to actual field data in various corrosive environments. The equation used for the corrosion is $C(t) = A*t^B$, where A is a random variable based on field measurements, B is generally a constant based on different corrosive environments and C(t) is the corrosion in micromils/yr.[4] For this report, the mean value of A was selected based on submerged corrosion since the portion of the gate that was being investigated is always below lower pool. This distribution used for A was a truncated lognormal with a mean value of 77.33 and standard deviation of 24. The upper limit of the distribution was taken at 128 and the lower limit at 32. The value for B was a constant of 0.593. These limits and constants are based on actual field measurement of submerged hydraulic steel structures.

C) Stress Concentration and Pintle Misalignment/Wear Factors. Two types of factors are utilized in the reliability model to account for differences in stress values between traditional hand calculations and finite element analysis. One adjustment is the stress concentration factor due to the intensification of the stress in the flanges near the pintle area. Separate local finite element models specific to each miter gate group were run to determine group-specific stress concentration factors, thus, not all sites used the same values for input. Additionally, a gate misalignment and pintle wear factor that accounts for an increase in stress in the girder flange during operation is provided in the analysis. The adjustment values for both the stress concentration and misalignment/pintle wear factors were based upon finite element modeling results and calibration with field test data at Markland. The distribution for the stress concentration factors was considered uniform, meaning that any number within the specified range has equal chance of being selected in an iteration, since only the upper and lower limits can be well defined as well as the equal for the probabilities. For Group 1 (Greenup, Markland, etc.), the minimum stress concentration factor value was determined to be 1.1 and the maximum value to be 1.4. For Group 2 (Cannelton, etc.), the minimum value was determined to be 1.2 with a maximum of 1.8. For Group 3 (J.T. Myers, etc.), the minimum stress concentration factor value was determined to be 1.4 and the maximum value to be 2. The misalignment and pintle wear factors were determined on a percentage increase in the flange stress. A truncated lognormal distribution was selected with a mean of 20% with a standard deviation of 30%. The lower limit was 10% and the upper limit taken as 50%. Again, these values were calibrated with the field measurements relating to cracking at Markland and were assumed to be the same for all groups.

5.2.9 HWELD Reliability Model for Horizontally-Framed Miter Gates

A) Reliability Model Purpose. The computer program HWELD has been developed to complete a reliability analysis of the horizontally-framed miter gates for Ohio River lock projects. The model is used to determine if it is a better decision to replace the gates at some scheduled date as opposed to fixing them after they perform unsatisfactorily.

B) Reliability Analysis. The basis of the model is that it is a time dependent reliability model for a structure subject to fatigue and corrosion. Therefore, input items such as paint history, corrosion rates, and other variables are used in conjunction with the operating cycles to determine the time dependent reliability of the structure. Using the analysis and limit state information from the finite element modeling, HWELD computes the time dependent reliability of the miter gates given the input values. For each iteration, the model determines the year in which a fatigue-related crack initiates and marks that year. Once the crack reaches the first length, the crack is allowed to grow relative to the operating cycles within the histogram for each year after the time which it initiates. The crack then grows until it reaches the critical lengths input in the menu. Once the crack grows to the flange length, the growth rate is reset for the second growth rate associated with it growing along the web/flange connection. Once the crack reaches the limit state crack length, the year is tracked, recorded and marked as the year of unsatisfactory performance. This is done for each iteration with the results tabulated in a separate output file.

C) Baseline Condition. The baseline condition is generally the way that maintenance is performed at each project today. This is typically inspection and repair during scheduled dewaterings with no overall improvement to the overall reliability of the gates. The baseline condition for the miter gates assumes that the structure does not receive any major rehabilitation, painting, or repairs from the start of operation to the end of study period, unless the miter gates have been painted prior to present day. The baseline condition also assumes a paint life of 20 years and that corrosion of the girder members occurs over the remaining study period, unless it has been totally sandblasted and painted.[5] The corrosion rate is always assumed to be for a submerged structure since that is the portion of gate being analyzed.

D) Calibration of HWELD Reliability Model. The calibration of the HWELD reliability models was made based on field data of crack lengths for Markland. These measurements and repairs were taken at two points in time (1994 and 1996) during lock dewaterings to fix and repair cracks in the welds in the pintle area. Since the HWELD program is based on the realistic flange stresses for the head values of the miter gates at Markland, the crack lengths and expected probability of failures determined from the model match well and support the field data.

5.2.10 HWELD Reliability Model Results and Event Trees

The Engineering Team is required to take the results from the reliability model, which are hazard functions for time dependent components, and supply them to the ORMSS Economics Team for their analysis and input into the Ohio River Navigation Investment Model (ORNIM). The hazard functions provided by HWELD represent the probability of unsatisfactory performance for a single gate leaf. Systems reliability applications must be used to incorporate the probability of unsatisfactory performance for all 4 miter gate leafs within a single lock chamber. For most projects, the upper and lower miter gates within the same lock chamber are of the same design and have seen most the same repairs and operational cycles. Therefore, the reliability of a single leaf essentially will be same for the other 3 gate leaves. All four leaves must be reliable for the chamber to be operational, thus, all 4 leaves are in series since the "failure" of any single leaf would shut the lock chamber down for some period of time. If significant repairs to improve the reliability of selected leafs have been completed, this improvement in reliability for that particular leaf was included in the analysis. Therefore, the calculation to determine reliability for the miter gates for an entire lock chamber, which is embedded in the economic analysis, is shown below.

$$R_{\text{Miter Gates}} = R_{\text{Leaf1}} * R_{\text{Leaf2}} * R_{\text{Leaf3}} * R_{\text{Leaf4}}$$

$$\textbf{HAZARD RATE}_{\text{Miter Gates}} = 1 - R_{\text{Miter Gates}}$$

For those sites where upper and lower miter gates have different miter gate sill heights (upper and lower miter gates are not of the same design), there are separate hazard rates developed for the upper and lower miter gates. For these miter gates, only 2 leaves would be in series. This is only applicable for the New Cumberland and Pike Island sites. In addition to the time dependent hazard rates, the Engineering Team supplies a consequence event tree for each component that is used in conjunction with the reliability analysis for the economists to measure the economic impacts associated with each component. The event tree for the horizontally-framed miter gates is shown in Figure ED 5-17. The event tree is set up to investigate replacing both the upper and lower miter gates within a lock chambers since both sets of gates have the same level of reliability.

A) Baseline Condition for Miter Gates. The baseline condition represents a fix-as-fails plan with respect to the reliability analysis. It is assumed that any repairs that are done to the miter gate during normal scheduled dewaterings do not upgrade the reliability of the miter gate because these repairs typically only consist of replacing pintles, miter and quoin blocks, etc. These repairs do not significantly upgrade the structural reliability of the miter gate based upon the limit state set up in reliability model. Therefore, the reliability of the structure is allowed to degrade through time without repairs under the baseline condition.

For the purposes of this study, the hazard function is defined as the probability of unsatisfactory performance in a given year assuming it has survived up to that year. The formula for this is depicted below:

$$h(t) = \textit{number of failures in year } t \,/\, \textit{number of remaining survivors up to year } t$$

The computation of $h(t)$ yields a yearly probability of unsatisfactory performance given that the miter gate has survived up to that particular year. The probability of unsatisfactory performance is tied to the limit state for the component (i.e. critical crack lengths reached on two lower girders for the horizontally-framed miter gates).

B) Baseline Condition Event Tree. The baseline condition is the scenario upon which all without project alternatives are compared against. The event tree for the miter gates was assumed to be the same for all projects with the same miter gates design on the upper and lower end of the lock chamber, which is the case for all projects except New Cumberland and Pike Island. Assuming the limit state for the miter gates as described previously and the need to investigate replacement for all four miter gates leaves within a chamber, the event tree shown in Figure ED 5-17 was developed for the horizontally-framed miter gates. Like all components, the repair branches of are developed by a consortium of engineering and operations personnel. The engineers and operations experts believed it was a more accurate reflection to increase the chance of more significant failure consequences with the age of the structure. Therefore, individual branch probabilities for components were linked to the age of the component. Regardless of the level of damage selected, the event tree represents a fix-after-failure situation because the miter gates already reached the critical limit state for which the hazard rate was developed. Thus, the repair is only initiated in the economic model once the gate "fails". The

event tree for the miter gates at New Cumberland and Pike Island are structured in a similar manner, but formatted to replace a single set of miter gates (2 leaves). Because the gates for both the main and auxiliary chamber are the same design and construction technique, the same event tree is used for both the main and auxiliary chambers. However, economic results will differ for the auxiliary and main chambers as a function of navigation traffic and the hazard rates. The first branch of the event tree represents the annual hazard rate for the miter gates. The hazard rate changes depending upon the chamber which is being investigated. The second branch indicates various options associated with the level of repair for the miter gates. Since the limit state is based upon a major failure, minor repairs were neglected in the event tree. The group decided that minor repairs to the miter gates are taken care of during normal maintenance dewaterings and they do not affect the overall gate reliability. The percentages associated with each level of repair were determined from engineering judgment in consultation with Operations personnel. Associated with each of these repairs is a repair cost and chamber closure time. The loss of benefits associated with the chamber closure is modeled in the economic analysis by way of transportation delay curves. Finally, the last branch updates the reliability in the next year based upon the repair. A further breakdown of the event tree from the level of repair forward is provided below.

Catastrophic Failure, Install New Gates. This repair assumes the most catastrophic event, a total failure of one of the set of miter gates such that is not repairable to the point that the chamber can be made operational. Since the other gates would be of similar reliability, it is assumed these gates would also require replacement since they are in the same general condition. This repair assumes two new sets of miter gates are fabricated, delivered, and installed over a two-year period. There are no spare gates at any Ohio River projects, therefore, new designs and fabrications would be required to get the chamber operational again. Additionally, a repair cost of $33,100,000 is assumed for this repair. It is known that the Louisville Operations Repair Fleet costs on average about $100,000 per day including materials for emergency type of repair works. This cost was determined based upon recent emergency dewaterings at both the Markland and McAlpine lock chambers. The assumption is made that the repair fleet would need to be on-site approximately 90 days to conduct salvage operations for the failed miter gates in the first year. The first year would also be used to develop an emergency design and initiate fabrication of a pier at the site to assemble two new sets of miter gates delivered to the site in sections. Fabrication of the miter gates would be completed in the 2nd year and then the miter gates would be installed. Another additional 90 days is required in year 2 to install both sets of miter gates. Therefore, the repair costs for the new gate repair level and how they were determined is shown as follows:

Repair Fleet Pulls Damaged Gates Repairs (Year 1):	$9,000,000 ($100k/day for 90 days)
Construction of Miter Gate Assembly Pier (Year 1):	$1,500,000 (Markland Rehab)
Fabricate and Delivery of 4 Gate Leafs (Year 2):	$10,000,000 (McAlpine new gates)
Assembly of 4 Gate Leafs on Pier (Year 2):	$3,600,000 (McAlpine new gates)
Installation of 4 Gate Leafs in Chamber (Year 2):	$9,000,000 ($100k/day for 90 days)
~~**Total for All Items for Catastrophic Repair:**~~	~~**$33,100,000**~~

This repair scenario is deemed the least likely to occur for most years of the effective life of the miter gates. As discussed previously and shown in Figure ED-17, a sliding scale has been provided such that the chance of this type of failure/repair increases as the miter gates age. This level has a 5% chance of occurrence during the first 30 years the miter gates

HORIZONTALLY-FRAMED MITER GATE EVENT TREE (2 SETS OF GATES)

ALL MITER GATES ARE SAME SIZE, AGE, AND GENERAL CONDITION

ANNUAL HAZARD RATE	LEVEL OF FAILURE & SUBSEQUENT REPAIR		CLOSURE TIME	REPAIR COST	DESCRIPTION OF REPAIR SEQUENCE	EFFECT ON FUTURE COMPONENT RELIABILITY
Annual Reliability Value (1 - Annual Hazard Rate)						
	Catastrophic Failure Requiring New Gates	5% 0-30 years of service	365 days in year 1	Cost $10,500,000	Fleet on-site for 90 days for salvage operations, assembly pier construction	Assume R = 1.0 for All Future Years
		15% 31-50 years of service	180 days in year 2	Cost $22,600,000	Miter gates fabricated, delivered, assembled, and installed (90 days fleet time)	
		30% Over 50 years of service				
Annual Hazard Rate	Major Repair but Gates Still Usable for Future	35% 0-30 years of service	45 days in year 1	Cost $4,500,000	45 days to repair 1st set of damaged miter gates	Move Back 5 Years
		30% 31-50 years of service	45 days in year 2	Cost $4,500,000	45 days to repair 2nd set of damaged miter gates	
		20% Over 50 years of service				
	Temporary Repair and Construct Assembly Pier	60% 0-30 years of service	60 days in year 1	Cost $7,500,000	60 days to repair existing gates plus assembly pier construction	Assume R = 1.0 for All Future Years
	Assemble 1st Set of Gates on Pier and Switch Out	55% 31-50 years of service	45 days in year 2	Cost $11,300,000	1st set of gates delivered to site, assembled/painted on pier, 45 days to swith out	
	Assemble 2nd Set of Gates on Pier and Switch Out	50% Over 50 years of service	30 days in year 3	Cost $9,800,000	2nd set of gates delivered to site, assembled/painted on pier, 30 days to swith out	

Figure ED 5-17. Horizontally Framed Miter Gate Event Tree

event tree for the miter gates at New Cumberland and Pike Island are structured in a similar manner, but formatted to replace a single set of miter gates (2 leaves). Because the gates for both the main and auxiliary chamber are the same design and construction technique, the same event tree is used for both the main and auxiliary chambers. However, economic results will differ for the auxiliary and main chambers as a function of navigation traffic and the hazard rates. The first branch of the event tree represents the annual hazard rate for the miter gates. The hazard rate changes depending upon the chamber which is being investigated. The second branch indicates various options associated with the level of repair for the miter gates. Since the limit state is based upon a major failure, minor repairs were neglected in the event tree. The group decided that minor repairs to the miter gates are taken care of during normal maintenance dewaterings and they do not affect the overall gate reliability. The percentages associated with each level of repair were determined from engineering judgment in consultation with Operations personnel. Associated with each of these repairs is a repair cost and chamber closure time. The loss of benefits associated with the chamber closure is modeled in the economic analysis by way of transportation delay curves. Finally, the last branch updates the reliability in the next year based upon the repair. A further breakdown of the event tree from the level of repair forward is provided below.

Catastrophic Failure, Install New Gates. This repair assumes the most catastrophic event, a total failure of one of the set of miter gates such that is not repairable to the point that the chamber can be made operational. Since the other gates would be of similar reliability, it is assumed these gates would also require replacement since they are in the same general condition. This repair assumes two new sets of miter gates are fabricated, delivered, and installed over a two-year period. There are no spare gates at any Ohio River projects, therefore, new designs and fabrications would be required to get the chamber operational again. Additionally, a repair cost of $33,100,000 is assumed for this repair. It is known that the Louisville Operations Repair Fleet costs on average about $100,000 per day including materials for emergency type of repair works. This cost was determined based upon recent emergency dewaterings at both the Markland and McAlpine lock chambers. The assumption is made that the repair fleet would need to be on-site approximately 90 days to conduct salvage operations for the failed miter gates in the first year. The first year would also be used to develop an emergency design and initiate fabrication of a pier at the site to assemble two new sets of miter gates delivered to the site in sections. Fabrication of the miter gates would be completed in the 2nd year and then the miter gates would be installed. Another additional 90 days is required in year 2 to install both sets of miter gates. Therefore, the repair costs for the new gate repair level and how they were determined is shown as follows:

Repair Fleet Pulls Damaged Gates Repairs (Year 1):	$9,000,000 ($100k/day for 90 days)
Construction of Miter Gate Assembly Pier (Year 1):	$1,500,000 (Markland Rehab)
Fabricate and Delivery of 4 Gate Leafs (Year 2):	$10,000,000 (McAlpine new gates)
Assembly of 4 Gate Leafs on Pier (Year 2):	$3,600,000 (McAlpine new gates)
Installation of 4 Gate Leafs in Chamber (Year 2):	$9,000,000 ($100k/day for 90 days)
Total for All Items for Catastrophic Repair:	**$33,100,000**

This repair scenario is deemed the least likely to occur for most years of the effective life of the miter gates. As discussed previously and shown in Figure ED-17, a sliding scale has been provided such that the chance of this type of failure/repair increases as the miter gates age. This level has a 5% chance of occurrence during the first 30 years the miter gates

chamber, the chamber closure time and "repair" cost is reduced when compared to replacing the gates only after they fail. It is known from an extensive collection of historical data that the Louisville District fleet averages roughly $67,000 per day for maintenance dewaterings that are well-planned in advance. That would be this type of situation. The main features of this would be to construct an assembly pier on site and begin fabrication of the 1st set of gates in year 1. Year 2 would include assembling and installing the 1st set of miter gates and fabricate the 2nd set of miter gates. The 3rd and final year of repair ahead of failure would be to assemble the 2nd set of miter gates and install them in the chamber. Separate 30-day closures would be required in years 2 and 3 of this repair scenario. The total cost estimate for the replacement ahead of failure option is estimated to be $19,120,000. A breakdown of costs associated with this scenario is as follows:

Construction of Miter Gate Assembly Pier (Year 1):	$1,500,000 (Markland Rehab)
Fabricate, Deliver of 2 Gate Leafs (Year 1):	$5,000,000 (McAlpine new gates)
Assembly of 2 Gate Leafs on Pier (Year 2):	$1,800,000 (McAlpine new gates)
Installation of 2 Gate Leafs in Chamber (Year 2):	$2,010,000 ($67k/day for 30 days)
Fabricate, Deliver of 2 Gate Leafs (Year 2):	$5,000,000 (McAlpine new gates)
Assembly of 2 Gate Leafs on Pier (Year 3):	$1,800,000 (McAlpine new gates)
Installation of 2 Gate Leafs in Chamber (Year 3):	$2,010,000 ($67k/day for 30 days)
Total for All Items for This Repair Level:	**$19,120,000**

5.2.11 Miter Gate Reliability Results for Single Chamber (Newburgh Main)

Because there is an overwhelming amount of data associated with the engineering and economic analysis on ORMSS, it is believed that the best way to clearly illustrate the entire process being followed for an individual component is to step completely through the process for a single lock chamber. Previous portions of this document give a detailed description of how the hazard rates were computed for an individual lock chamber miter gate. For the purposes of this narrative, the Newburgh main chamber miter gates were selected as a prototypcial lock chamber to step through the process. The optimized replacement date for the miter gates of all other lock chambers for each traffic scenario are provided at the back of this narrative in the Economics Appendix. When reviewing this table keep in mind individual traffic levels peak for different projects for different scenarios. Thus, the one traffic forecast might have the highest traffic at one project and a different scenario might be highest at another project.

Referring back to Figure ED 5-3, the miter gates at Newburgh are represented within Group 3. These gates are similar to the Markland (Group 1) gates with the exception that the pintle castings are bolted to the miter gate and not welded. Additionally, relatively thicker plates were used in design compared to Group 1 miter gates, thus, reducing the operating stresses, and generally causing lower hazard rates over time compared to Group 1. The Newburgh miter gates followed the limit state criteria that involves fatigue-related cracking of the girders at the end of the quoin diagonal plate. This was determined from the finite element analysis of the typical Group 3 miter gates.

The Lock Risk Module within ORNIM requires three sets of hazard rates to be developed for each component. These are the hazard rates associated with the lowest, highest, and middle traffic scenarios. These vary by each site, but at Newburgh the lowest traffic scenario was the Clear Skies, the highest was the NAAQS scenario, and the middle traffic scenario was the Utility High forecast. ORNIM will take these hazard rates and then interpolate between them to determine an updated hazard rate for traffic levels that fall between these "limits" when traffic demand is put onto the system in the economic simulation analysis. A graphical representation of the main chamber miter gate hazard rates at Newburgh for each of these traffic scenarios is shown in Figure ED-18.

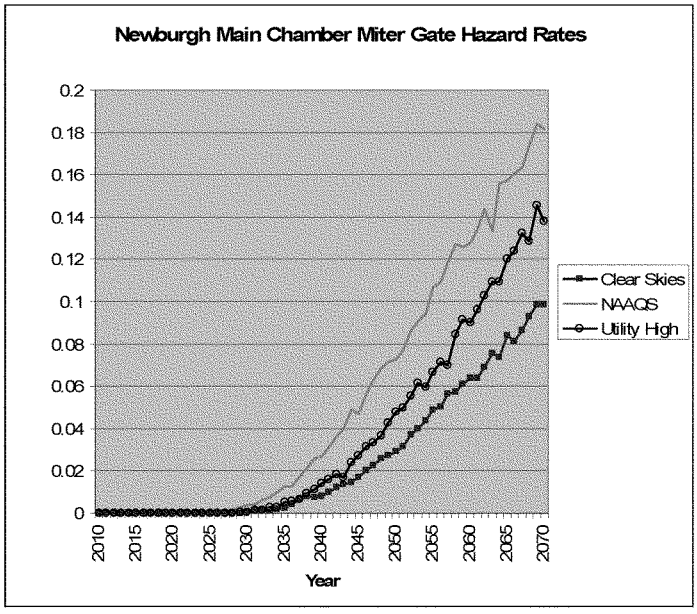


Figure ED 5-18. Newburgh Main Chamber Miter Gate Hazard Rates

As depicted in Figure ED 5-18, the highest traffic forecast (NAAQS) provides the highest hazard rate. The lowest traffic scenario at Newburgh (Clear Skies) is reflected in the reduced hazard rate through time. Forecast specific hazard rate computations from time of original service (1972) through the end of study (2070) were completed, but only the years which produced non-zero hazard rates are depicted in the figure for clarity sake. The first year of a non-zero hazard function was 2026 for the NAAQS scenario. Non-zero hazard functions for the other two scenarios first occurred in the year 2029 (Utility High) and 2030 (Clear Skies). The reason the hazard rates for the structural components take a "jagged" shape is due to the Monte Carlo simulation. In theory, the hazard rate would be smooth line increasing through time if an infinite number of iterations were run. A total of 50,000 iterations were run for each traffic scenario which is adequate for the purposes of this study.

5.2.12 Economic Analysis of Horizontally-Framed Miter Gates

The Engineering Team provides both the hazard rates, as shown in Figure ED 5-18, and the event tree shown in Figure ED 5-17 to the Economics Team for them to input into ORNIM. The other critical information for the main chamber miter gates provided to the Economics Team was the replace ahead of failure costs and closures as outlined in Section 5.2.10 of this appendix. ORNIM was then used to compute average annual costs for two repair options (fix-as-fails or replace ahead of failure) for the main chamber miter gates at Newburgh. The average annual costs include both navigation delay and physical repair costs. Improved reliability after the repair is also included in the analysis, as noted in the event tree for differing levels of repairs. The costs of each alternative, fix-as-fails versus selected replacement dates, are compared to determine the most economical option. The replacement

year with the lowest average annual cost sets the timed replacement of the miter gates with fix-as-fails costs added to the economic analysis up to the year of scheduled replacement. Refer to the Economics Appendix for a more detailed description of how the ORNIM optimizes individual component replacements. If the lowest average annual cost is associated with the baseline condition (fix-as-fails), then the replacement of the gates is not justified economically and the fix-as-fails costs are embedded into the overall economic analysis for every year of the study period. ORNIM produces a graphical output depicting the results and optimal timing of this process for each component and each traffic scenario. The ORNIM output for the Newburgh main chamber gates is shown for the Utility High traffic forecast in Figure ED-19.

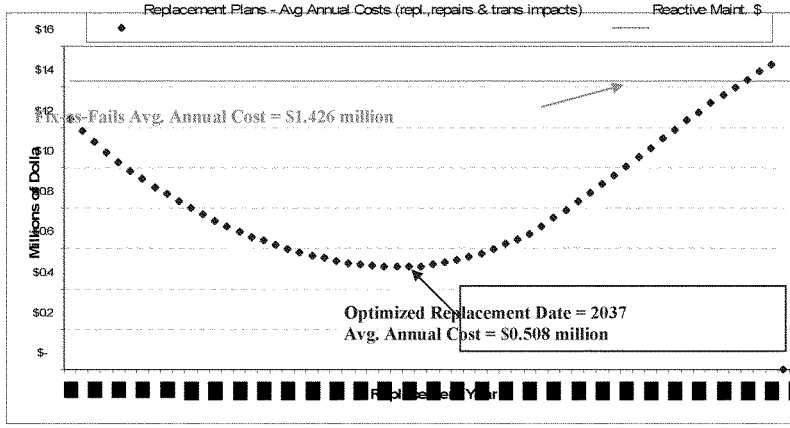


Figure ED 5-19. Newburgh Main Miter Gates Optimized Replacement Date (Utility High Traffic Scenario)

As noted earlier, the miter gates were evaluated for each traffic scenario. Using the same methodology, optimized replacement dates were determined for each traffic scenario. The projected replacement dates for each traffic scenario are provided in the Economics Appendix.

Please refer to the tables in the Economics Appendix for the optimized replacement date of all horizontally-framed culvert valves across the Ohio River projects. These are given for each lock chamber by traffic scenario.

5.2.13 References for Horizontally-Framed Miter Gate Reliability

1. "Fatigue Cracking Evaluation of the Markland Miter Gates," ANATECH Report ANA-96-0201 to Corps of Engineers, Louisville District, November 1996.
2. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, 1989 Edition, American Society of Mechanical Engineers, July 1989.
3. "Structural Inspection and Evaluation of Existing Welded Lock Gates," U.S. Army Corps of Engineers, ETL-1110-2-346, Sept. 1993.

4. Ellingwood, Zheng, and Bhattacharya. "Reliability-based Condition Assessment of Steel Miter Gates," Final Report Submitted to Black & Veatch Engineers, March 1996.
5. "Reliability Analysis of Hydraulic Steel Structures with Fatigue and Corrosion Degradation," WES Report, March 1994.

5.3 VERTICALLY-FRAMED MITER GATE RELIABILITY

There are only three projects on the Ohio River that utilize vertically-framed miter gates. These are the upper three sites on the Ohio River: Emsworth, Dashields, and Montgomery (EDM) Locks and Dams. Additionally, only the main chamber at these sites have vertically-framed miter gates, the auxiliary chamber at each site has horizontally-framed miter gates. Therefore, out of 38 lock chambers on the Ohio River, only 3 use vertically-framed miter gates. However, since this is a major component that can potentially have major consequences, a reliability model was developed for vertically-framed miter gates.

5.3.1 Background of Upper Three Projects (EDM)

The upper three Ohio River projects, EDM, are the oldest operating locks and dams on the Ohio River. These projects were built in the early 1920's and 1930's. The oldest is Emsworth which was completed in the early 1920's. Because of overall deteriorating conditions at each of the three projects, the locks at each site were rehabilitated in the mid-to-late 1980's. All major components, with the exception of dam gates and concrete, were replaced as part of this rehabilitation. Included in the work was the replacement of the existing main chamber, vertically-framed miter gates with newer, stronger vertically-framed miter gates. The existing, original miter gates were constructed of riveted, plate girders. The new miter gates installed during the rehabilitation are made of rolled wide flanged girders. This makes a significant difference in the reliability of the miter gates. Additionally, the new miter gates were considerably stronger in terms of the section modulus when compared to the older gates. The new gates are stressed considerably lower in terms of bending and shear under normal operating loads. This is a controlling factor in the fatigue analysis.

5.3.2 Background of Vertically-Framed Miter Gate Reliability Model

The reliability model for the vertically-framed miter gates was the Corps of Engineers first attempt to develop time dependent hazard functions for lock structures for the purpose of subsequent economic analysis. Therefore, the engineering team was required to develop the proper methodology for developing hazard functions for lock and dam components. The vertically-framed miter gates were selected first because a preliminary reliability assessment of the original vertically-framed miter gates at Emsworth had already been investigated by Dr. Bruce Ellingwood of Johns Hopkins University for the Pittsburgh District. The model that Dr. Ellingwood developed was based upon the limit state of fatigue of the main load bearing beams.[1] The ORMSS engineering team's first goal was to attempt and develop a reliability model for the vertically-framed miter gates using Dr. Ellingwood's previous work as a basis. The insight and guidance provided by Dr. Ellingwood's model proved to be quite valuable in the initial modeling efforts. However, some changes were required to the model developed by Dr. Ellingwood in order to establish the necessary parameters that could be used for all three upper Ohio River sites. The engineering team developed its initial model using the parameters from the older, built-up girder miter gates that were in place from the early 1920's until the rehabilitation in 1984. Once the reliability results from the new model compared well with the newly adjusted results from

Dr. Ellingwood's model, the team believed it had a model that was accurate within the confines of the analysis itself. This model was then used for the analysis of the new vertically-framed miter gates at EDM to determine their time dependent reliability.

5.3.3 Vertically-Framed Miter Gate Reliability Model Development

The vertically-framed miter gate model is quite different from the horizontally-framed miter gates. Whereas an original, Ohio River specific Visual Basic coded model was developed for the horizontally-framed miter gate reliability model, the spread sheet Microsoft Excel™ was used in conjunction with the Monte Carlo simulation software, @Risk™ for the vertically-framed miter gate reliability model. Additionally, the limit states selected for the vertically-framed miter gate model were the strength and fatigue of main, load carrying beams and the top horizontal girder. The horizontally-framed miter gate limit state was selected based upon field experience of fatigue cracking at specific connections around the pintle region of the gate. There are a couple of reasons that the process selected for the vertically-framed miter gates was chosen. Foremost, the process and limit state for the vertically-framed miter gates was the same one as Dr. Ellingwood had used in his previous modeling efforts. Since he had credible results, the engineering team wanted to calibrate the new model versus his initial results since this was the first attempt to develop a truly time dependent model.

5.3.4 Vertically-Framed Miter Gate Reliability Model Details

Probabilistic evaluation of the structural components was performed with the aid of spreadsheet and a simulation program. Variables were treated as random where needed with appropriate values obtained from either the literature, past records or a combination of calibration and engineering judgment. The model consists of a workbook within a spread sheet. The overall spread sheet contains four separate sheets defined as *Inputs, Outputs, Horizontal Girder*, and *Vertical Beam*. The *Horizontal Girder* and *Vertical Beam* sheets are the where the computations for the reliability of the structure take place. The model tracks both the performance of the miter gate from a strength standpoint (load vs. capacity) and fatigue standpoint (when the number of *unfactored* allowable cycles is reached).

INPUTS SHEET

This sheet contains all the input parameters for the model. Fixed values such as top of miter gate and miter gate sill elevations were obtained from the as-built drawings. Examples of random variables used are the yield strength of steel, structural analysis factor, corrosion variables, fatigue strength and tail water elevation. During each iteration, a new set of random values is generated. Each iteration tracks the miter gate through the study period until either a limit state is reached or the end of the study period is reached without a failure. Once either of these occurs, a new iteration is begun with the selection of new random variables. A simulation is completed once all the pre-selected number of iterations is completed. The tail water elevation is generated once at the beginning of each iteration and is kept constant for the life span (study period) of the structure for that particular iteration. A brief description of the variables used is provided below.

Pool Elevations. Tail water elevation is taken as a random variable and the upper pool is kept constant. Daily pool records are readily available at all ORMSS sites from Lock Performance Monitoring System (LPMS) data from about 1982 to present. The differential head is used for checking the bending limit state for both the strength and fatigue modes. Since the hazard function is developed on an annual basis, the strength mode of the model required the maximum annual head differential since that occurred each year. This was the load that was computed for each year for the strength limit state.

For the fatigue limit state, a histogram of number of lockages versus differential head was built from LPMS data. This histograms yields actual number of operating cycles versus differential heads for various ranges.

Material Data. Statistics for yield strength were obtained from the literature and steel yield strength is generated once at the beginning of each iteration. Fatigue capacity (factor log c) was treated as a random variable and generated for each iteration. Another factor that was treated random is the corrosion rate, which depends on the material and the surroundings. Corrosion rate is different for atmospheric, splash and submerged regions. All random variables were selected once at the beginning of each iteration and kept constant throughout that particular iteration.

Corrosion. The cumulative number of years during which corrosion takes place is referred to as the variable t. Note that periodic painting affects the corrosion rate and must be taken into account in the

analysis. In the analysis, corrosion is treated as a random variable. Taking corrosion as:
where the penetration rate, C(t), with units of μm/year, is expressed as a function of time. The variable A, the rate parameter, is log-normally distributed with a mean, $\mu = 140$, and standard deviation, $\sigma = 42$, for the splash zone. The constant B, the time-order parameter, is an experimentally observed parameter and is treated as a deterministic value equal to 2/3.[1] Knowing the thickness at time t, the section modulus, S(t), with respect to time in terms of a variable flange and web thickness is computed.

Fatigue. Fatigue damage is based on the S-N curve and the data available in the literature, where S represents the stress and N represents the number of allowable cycles.

$N = C / (\text{stress range})^m$, where N = allowable cycle
C = variable depending on weld type
m = experimentally observed constant

Variable C is treated as random; statistics of C were taken from literature and is dependent upon the type of existing welded connection.

Hydraulic Cycles. Available records of lockages were used to obtain the hydraulic load cycles on the structure from installation through the present date. A load cycle is referred to as a complete filling and emptying of the chamber. For the future years, forecast by the economists must be provided to determine future reliability.

Analysis Factor. The moment demand is variable because of assumptions and inaccuracies in analytical procedures. This can be introduced by the factor B(I), which is log-normally distributed with mean, $\mu = 0.964$, and standard deviation, $\sigma = 0.12$. B(I) is an experimentally determined value for a vertical beam in a vertically framed miter gate. The value for B is different for the horizontal girder.[2]

COMPUTATION SHEETS

The computations are carried out in two sheets, *Horizontal Girder* for the top girder and

Vertical Beam for the vertical beams that transfer loads to the top horizontal girder. There are two failure modes (i.e., limit states) for both the vertical beam and horizontal girder, namely strength (in bending) and fatigue. Both modes consider the cumulative effect of corrosion and the paint history of the respective site. Calculations are performed in a similar manner for both components.

Random variables are first generated at the beginning of each iteration in the *Inputs Sheet*. For each iteration (i.e., life span of the structure), the properties are calculated considering the changes in dimensions due to corrosion and paint history.

The strength mode limit state was defined by mid-girder flexure for both the vertical beam and horizontal girder. For both the beam and the girder, the limit state is defined as "demand exceeds capacity." There are no safety factors or other criteria applied to either the demand or capacity side of the equation. The capacity is determined for each iteration by the random variable selected for the yield strength of the steel and the amount of corrosion on the structure. This is checked against the demand from the load and if the demand exceeds the capacity any time, the year it occurs is noted for each iteration. At the end of a simulation, annual unsatisfactory performance occurrences are tabulated for each year and hazard functions are computed with the help of a macro.

The hazard function, h(t), is the negative derivative of the natural log of L(t), or:

$$h_t = -d(\ln L_t) / dt.$$

h(t), therefore, is the negative slope of the curve defined by the function ln (L(t)). In the literature, h(t) is defined as the conditional failure rate in a given time period. That is, hazard rate is the probability of an unsatisfactory performance within time increment t, given the structure has performed satisfactorily from time zero up to time t. The hazard function is computed numerically using the output data from simulation

The fatigue mode limit state is also defined by demand versus capacity. Demand is the cumulative effect of fatigue damage at the mid-span for the beam connection type. Fatigue damage was defined as the ratio of actual number of load cycles to allowable number of load cycles for a constant amplitude loading. The stress that causes the fatigue is not constant for all load cycles. Thus, a head versus percentage of operating cycles histogram was built based on the LPMS data for each of the three project main chamber locks. The histogram partitions the total number of load cycles into appropriate stress categories. The standard Miner's Rule is used to sum the fatigue damage of variable amplitude loading and it is considered unsatisfactory when the cumulative damage exceeds unity. Similar to the strength case, macros in the spreadsheet are used to calculate the hazard function for the fatigue mode.

Outputs Sheet

The *Outputs* worksheet lists the time-dependent reliability and hazard rates for the two limit states considered for each of the component, fatigue and strength of both the vertical beam and horizontal girder. Graphs are also provided once the computation of the hazard function is completed in this worksheet. These results are sent to the economists when appropriate along with an event tree.

5.3.5 Model Results and Conclusions

The model was built for the purpose of determining time dependent reliability of vertically-framed miter gates. Once the model was completed, the first item to "test" was the performance of the

original Emsworth upper, main chamber miter gates. These gates were installed when the structure was built in the early 1920's. They were replaced during the rehabilitation of the Emsworth project in the early 1980's. It is known that the original miter gates were in very poor condition when they were replaced. Therefore, the actual reliability of the original miter gates was quite low when they were replaced. After making the appropriate adjustments during the construction of the model, the original miter gates at Emsworth were tested with the new ORMSS vertically-framed miter gate reliability model to determine their time dependent reliability. The results were excellent. Using the correct date for historical painting dates and operating cycles, a high hazard rate was computed for the miter gates by the early 1980's. These results compared well with the results that Dr. Ellingwood had for the initial modeling effort once the proper results were made to that model.

With confidence that the new model was yielding accurate results within the confines of the analysis itself, the team collected the necessary information to make the reliability runs for the main chamber miter gates at EDM. It was evident once the initial results were computed that the hazard rate for the main chamber miter gates would be extremely low throughout the study period for each of the three projects. In reviewing the properties for the new gates, the team found the answer to why the hazard rate appeared to be so low. The new miter gates that were installed were vastly improved over the older design. The old miter gates were constructed of riveted, built-up plate beams and girders. For the limit states that we were investigating, these are the worst type of construction details for fatigue. The new gates (installed during the rehabilitation) were made of rolled wide flange sections. Additionally, the section modulus had been increased by over three times when compared to the original miter gate beams and girders.

Therefore, the model was giving correct values for the time dependent reliability of the vertically-framed miter gates for the selected limit states. The hazard rates were computed as zero for each of the main chamber miter gates. Without a hazard rate, the economists were not required to make an economic analysis of the vertically-framed miter gates, thus, an event tree was not required.

In conclusion, the replacement of the vertically-framed main chamber miter gates for the selected limit states is not justified during the study period at any of the three projects. This does not indicate that there will never be any problems associated with the miter gates. Operational problems will be encountered, but repairs are handled through normal and major maintenance.

5.3.6 References for Vertically-Framed Miter Gate Reliability Analysis

1. Ellingwood, B.R., Zheng, R., and Bhattacharya, B. (1996): "Reliability-based Condition Assessment of Steel Miter Gates." Report by Black & Veatch to U.S. Army Corps of Engineers.
2. Padula, J., Chasten, C., and Mlakar, P. (1995): Reliability of Hydraulic Steel Structures with Fatigue and Corrosion Damage. CESEC 1995.
3. EM 1110-2-2703 (1994): Lock Gates and Operating Equipment
4. Ellingwood, B.R. (1993) Load and Resistance Factor Design for Steel Miter Gates, CEWES Instruction Report ITL-93-4.
5. Commander, B.C., Schulz, J.X., Goble, G.G., and Chasten, C.P. (1993) Computer-Aided, Field-Verified Structural Evaluation, Report 3, Field Test and Analysis Correlation of a Vertically Framed Miter Gate at Emsworth Lock and Dam, CEWES Technical Report ITL-92-12.

5.4 HORIZONTALLY-FRAMED REVERSE TAINTER CULVERT VALVE RELIABILITY

Reverse tainter culvert valves at Ohio River projects are used to control the filling and emptying of lock chambers. All sites with the exception of the upper three (Emsworth, Dashields, and

Montgomery Locks and Dams) utilize reverse tainter culvert valves for the filling and emptying of the lock chamber. Emsworth, Dashields, and Montgomery (EDM) utilize butterfly valves for the operation of their filling and emptying systems. Butterfly valves are covered within the overall mechanical model. There are two types of reverse tainter culvert valves: horizontally-framed and vertically-framed. Separate reliability models had to be developed for each of these reverse tainter culvert valves.

Most Ohio River projects use vertically-framed reverse tainter culvert valves, however, there are several sites with horizontally-framed valves. In general, the older sites use horizontally-framed culvert valves. These include the valves at Pike Island, New Cumberland, Greenup, Meldahl, Markland, and the existing main chamber at McAlpine. The newer projects have vertically-framed valves. These sites include Willow Island, Belleville, Racine, Hannibal, R.C. Byrd, Cannelton, Newburgh, J.T. Myers, Smithland, and Olmsted. This section will focus on the horizontally-framed culvert valves. Section 5.5 of this appendix focuses on vertically-framed culvert valve reliability.

Most of the horizontally-framed reverse tainter culvert valves in use on the Ohio River have been in operation since the late 1950's to early 1960's. The design and construction technique for the main and auxiliary chamber valves at all the sites are the same, therefore, the same reliability model can be used for each chamber with chamber specific input for historical painting and operating cycles. Additionally, the culvert valves designs between projects with horizontally-framed culvert valves is similar enough that the same global finite element model was developed and used for all projects to determine load distributions, stress concentration factors, etc. It is important to note that the significance of an unsatisfactory performance of a reverse tainter culvert valve is quite different depending upon whether it occurs in the main or auxiliary chamber.

5.4.1 Main Chamber vs. Auxiliary Chamber

The main chamber at all sites, with the exception of EDM, has a total of four reverse tainter culvert valves for filling and emptying the lock, two filling and two emptying valves. One filling and emptying valve is in the middle wall and the other set is in the river wall. They can be operated independently. Therefore, a repair to one of the main chamber culvert valves does not necessarily close the chamber. It is possible to dewater the area around the valve only, thus, leaving the other filling and emptying set to operate the chamber. Filling and emptying time is roughly doubled over normal operation. Normal filling and emptying time for a typical 1200 foot lock on the Ohio River is approximately 8 minutes each.

For the auxiliary chamber, there are two valves to control filling and emptying operations. One filling and emptying valve each. Therefore, a problem with one of the valves on the auxiliary chamber closes the entire chamber while necessary repairs are made. The significance of closing the auxiliary chamber is considerably less than the main chamber, however, loss of navigation benefits associated with an extended auxiliary chamber closure can become large.

5.4.2 Description of the Horizontally-Framed Culvert Valves

The valves are termed horizontally-framed since the main load from the skin plate is transferred to large vertical plate girders by a series of horizontal girders. The large vertical plate girders transfer the load to a series of axially-loaded strut arms that connect the body of the valve to a pin plate casting, which transfers the load to the valve's trunnion beam. The trunnion beam then transfers the load to the concrete monolith. The valves act in tension since the tainter gate is reversed to the direction of flow. Photographs of the valves a typical Ohio River horizontally-framed reverse tainter culvert valve are shown in Figures ED 5-20 through ED 5-24.

Because of the complexity of these structures and the potential redundancy associated with them, a global finite element model for the Markland culvert valve was developed to determine areas

of high stress concentration. Again, this valve is typical of other Ohio River horizontally-framed culvert valves. Additionally, the problems associated with the miter gates at Markland caused concern for the valves since these structures also had large amounts of welding that may lock in residual stresses. For a more detailed description of the fatigue problems associated with residual stresses at Markland, refer to Section 5.2 of this appendix which covers the reliability modeling of the horizontally-framed miter gates.

It was determined from the finite element modeling of the horizontally-framed culvert valve that there were two areas of high stress concentration during normal operation. The two locations were where the strut arm transitions and connects to the pin plate casting. The other location was where the horizontal girders are connected to the vertical plate girders. It was decided to concentrate on the strut arm connection since there is little to no redundancy associated with this connection. Additionally, Louisville District Operations personnel familiar with the Markland culvert valves have stated that this connection has caused concern over the years.

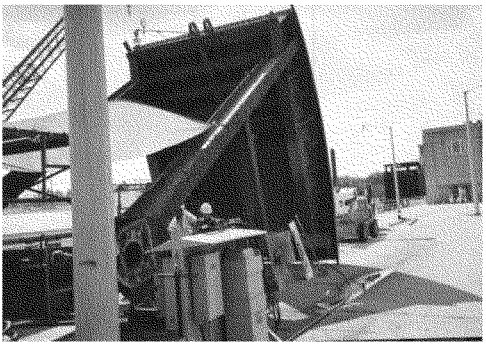


Figure ED 5-20. Side View of Markland Reverse Tainter Culvert Valve

5.4.3 Finite Element Modeling of the Culvert Valves and Calibration

The same basic procedure and steps used to develop reliability models for fatigue cracking at welded connections for the miter gates were employed for the reverse tainter culvert valves. The differences are that, for the culvert valves, direct tensile loads act on structural members and connections, and that the impinging water loads are significant, both in amplifying the load and in area reduction due to erosion-corrosion effects (note pitting of strut arm in Figure ED 5-23). To compensate for these effects, the design of culvert valves use a much higher factor of safety by increasing load factors for design loads and reduced design stress allowables. The development of the reliability model requires the same basic steps of characterizing crack initiation, crack growth rate, and definition of the limit state but requires different criteria and methods.

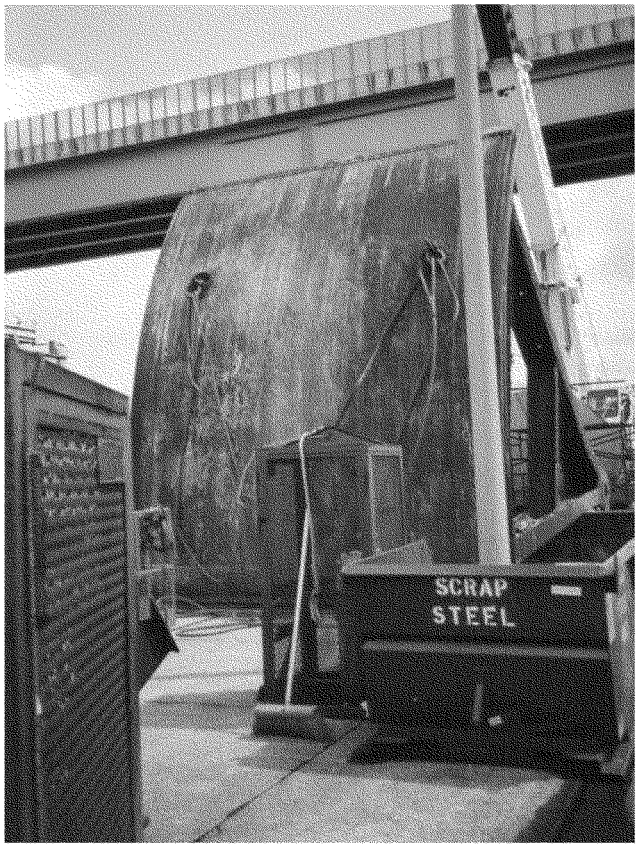


Figure ED 5-21. Front View of Markland Reverse Tainter Culvert Valve.
Note surface deterioration of skin plate

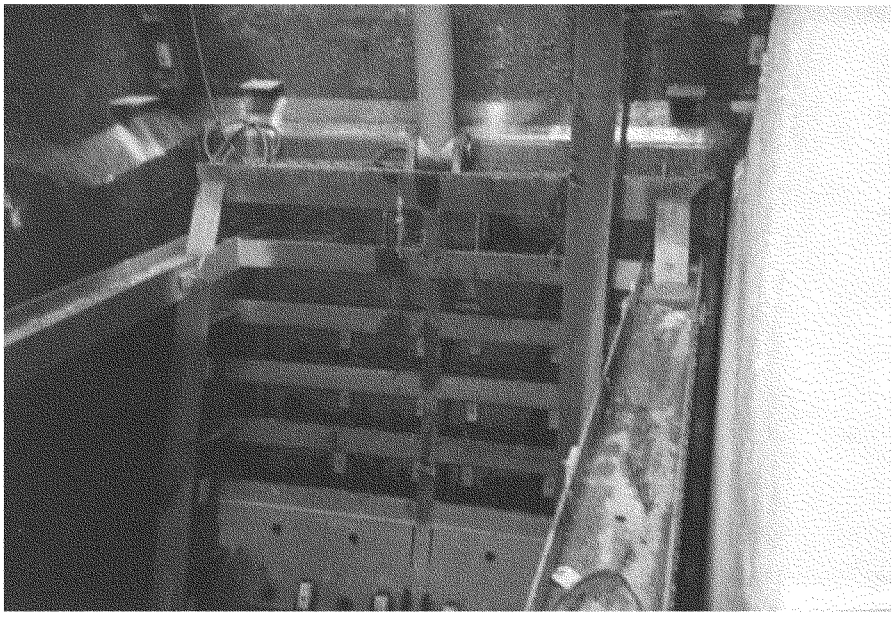


Figure ED 5-22. Markland Culvert Valve in the Pit
Note the corrosion of the valve relevant to the spot-painted areas

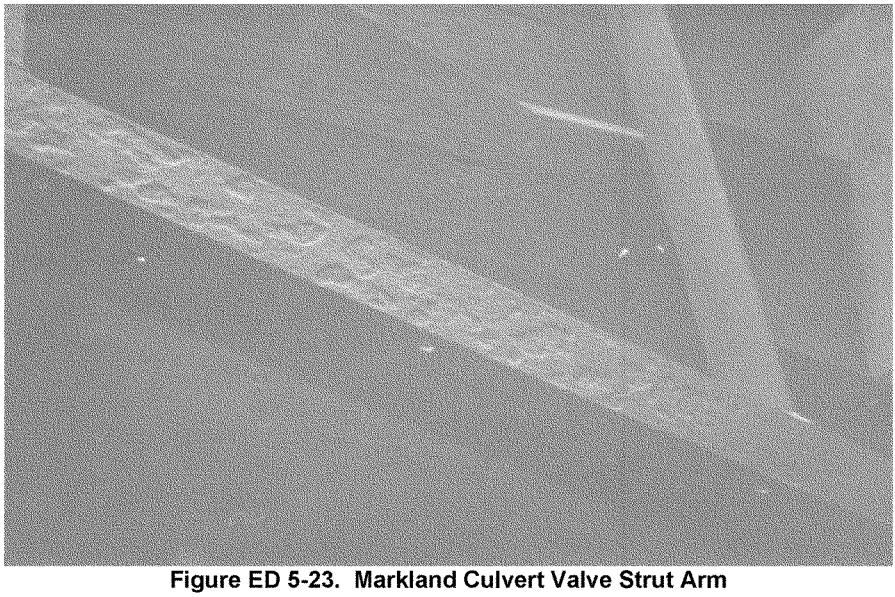


Figure ED 5-23. Markland Culvert Valve Strut Arm
Note heavy pitting and corrosion of strut arm

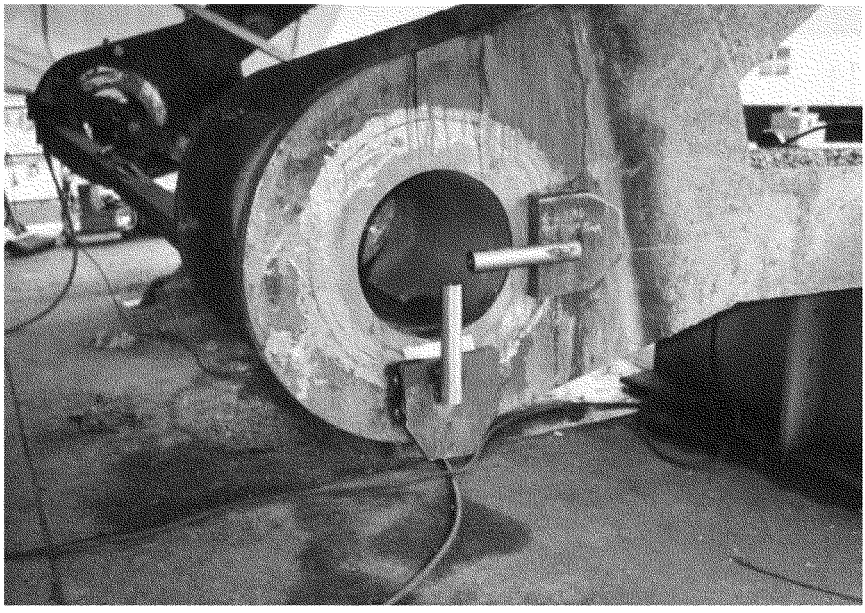


Figure ED 5-24. Markland Culvert Valve Bushing
Photograph depicts connection of valve body to pin plate casting

The first step is to evaluate the stress distributions in a global model of the culvert valve to identify locations where fatigue cracking can lead to reliability problems. A global model of a culvert valve was constructed using half symmetry, and areas of stress concentrations were evaluated for applied operating load conditions. Two areas showing the highest stress concentrations are identified, and refined meshes are incorporated into the global model for these areas. Figure ED 5-25 illustrates the global modeling for the culvert valve with the mesh refinement at the potential cracking areas. One area is the welded connection for the flange of the vertical load girder attached to the web of the strut arm. The other area for investigation is the welded connection of the strut arm flange to the trunnion pin casting. Global model calculations are conducted using a normal operating head of 30-ft (uniform pressure load) to determine the likely alternating stress ranges for crack initiation at these stress concentration areas. Adjusting for the nominal residual stress of 20 ksi tension at these connections gives alternating stress ranges of about 11 ksi at the girder flange to strut arm web connection and 9.5 ksi for the strut arm flange to trunnion pin block connection. Thus, cracking would initiate first at the girder flange to strut arm web connection. However, by considering the limit state involved at these two connections, it was determined by the engineering team that the strut arm connection to the trunnion pin block is the more critical for reliability.

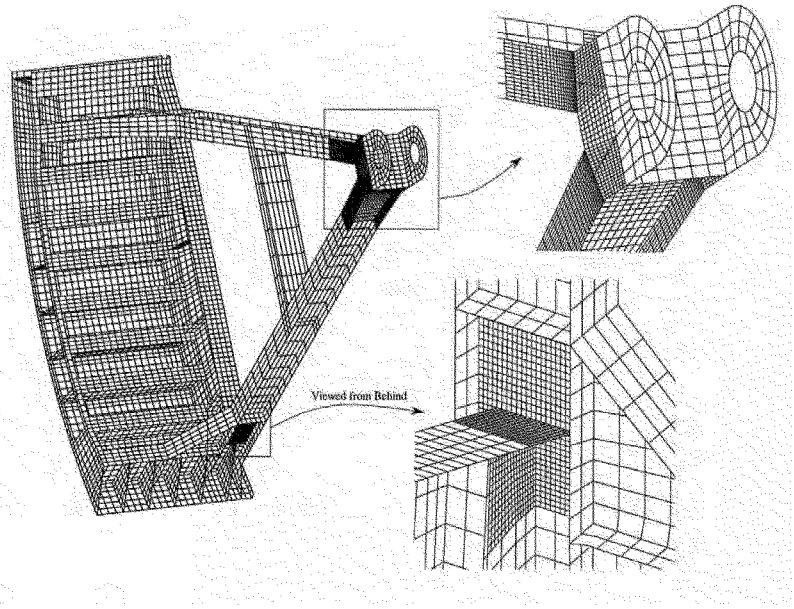


Figure ED 5-25. Global Finite Element of Horizontally Framed Culvert Valve

The engineering team then established the variables to characterize in the reliability model for fatigue cracking at the strut arm connection to the trunnion pin block. The residual stress at the welded connection is a function of the yield stress. Because of schedules and budget, detailed residual stress calculations of this connection were not employed. However, based on past experience, it is known that tensile residual stresses will develop during the welding of the connection. Since detailed calculations were not performed, a larger random variation is used for the residual stress as a function of yield stress. The operating loads develop tensile stress at this connection that will depend on the operating head and the amount of thickness reduction due to erosion-corrosion. Thus, a matrix of calculations were performed using head variations and thickness reduction of the strut arm flange to determine the maximum principal stress at the connection as a function of head (in feet) and thickness reduction (in inches) as shown in Figure ED 5-26. An equation was developed to fit this variation. For crack initiation, it is assumed that the valve open cycle produces a zero peak stress at the connection. The alternating stress is then determined from ½ of the maximum principal stress as a function of the random variables and adjusted for residual mean stress.

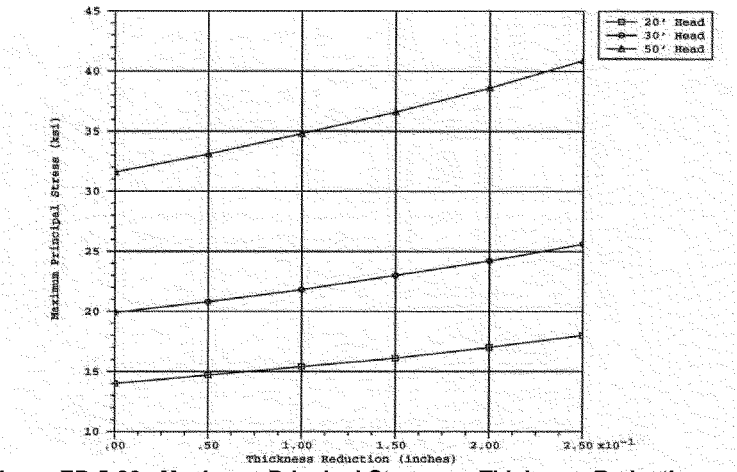


Figure ED 5-26. Maximum Principal Stress vs. Thickness Reduction as a Function of Head

The crack growth rate is now determined by extending a crack at the connection and calculating the stress intensity value versus crack length from the J-integral. Again, detailed residual stress calculations were not performed to establish the residual stress around the welded connection. However, because the crack is extending along the weld line for this case, it is assumed that the residual stress distribution is fairly constant along the path of the crack. Then, since fatigue crack growth is governed by the stress difference over the operating cycle, the residual stress will cancel out in determining the change in stress intensity. The magnitude of residual stress will affect the growth rate and this effect gets included in calculating the exponent on the change in stress intensity in the Paris relation. The fatigue crack growth rate is determined for a reliability model by conducting a matrix of analyses with variations in head and thickness reduction. For each combination, the crack is extended and the stress intensity computed for an open and closed valve condition. The resulting stress intensity versus crack length relation for that combination of variables is used to integrate the Paris relation to obtain number of cycles versus crack length as illustrated in Figure ED 5-27. An equation is then developed to fit this data that can return an increment in crack extension for a given increment in the number of cycles on a current crack length.

5.4.4 Limit State for Horizontally-Framed Reverse Tainter Culvert Valves

Once the crack initiation and fatigue crack growth rate are characterized, the limit state of the culvert valve must be established. The limit state is defined as the extent of fatigue cracking that will compromise the structural integrity of the culvert valve. As mentioned in the previous section, the first step was to determine which of the two areas identified for potential fatigue

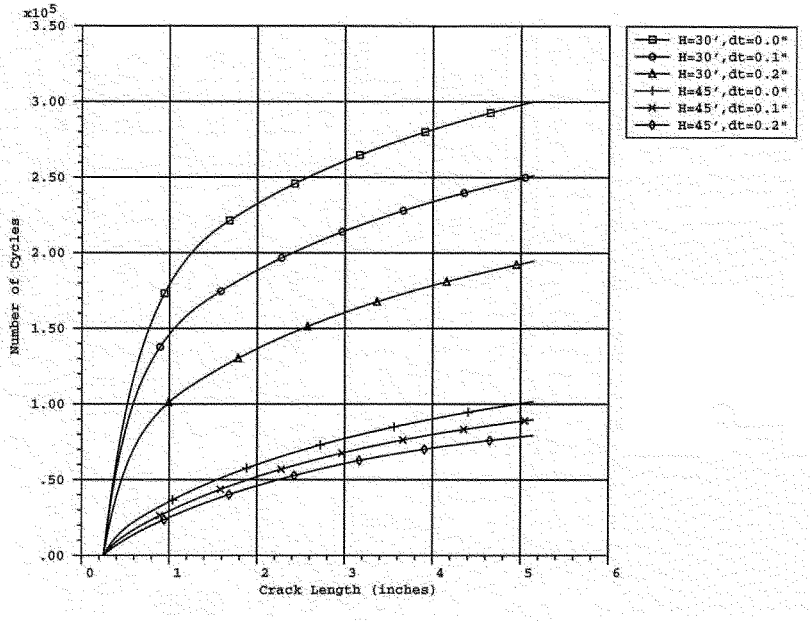


Figure ED 5-27. Crack Length vs. Number of Cycles as a Function of Head, Thickness Loss

cracking was the more critical for valve integrity under crack growth. To this end, extensive cracks were introduced in the finite element model at the two locations to evaluate the potential consequences. The top flange of the vertical load girder was completely disconnected from the welded attachment to the web of the strut arm. Under operating loads, the stress was redistributed to the web of the vertical load girder. Although stress concentrations were attracted to this new area, excessive deformations or stresses did not develop in the damaged area. This implies that cracking would continue to develop at this location, but that fairly extensive damage may be needed before the structural integrity is compromised. On the other hand, extending a crack in the flange of the strut arm connection to the trunnion pin block caused increased stress concentrations to develop ahead of the crack since a direct reduction of area on a tension member occurs. Thus, fatigue cracking here will undoubtedly progress into a failure of the valve. Therefore, this connection was judged by the engineering team to be more critical and was used to develop a reliability model.

The next step is to determine the extent of cracking that is considered the limit state for the valve. Since this connection is cycled from near zero load to tensile loads, buckling cannot be used to determine a limit state as was done for the miter gate flange connections. Linear elastic fracture mechanics formulas were considered for defining a critical crack length for brittle fracture. However, the size of the connection and the assumed fracture toughness for the material makes this connection very resistant to brittle fracture. Thus, criterion was established for the amount of plastic yielding ahead of the crack to determine the limit state. As the crack extends, the stress concentration increases at the crack tip and the amount of plastic yielding will steadily increase. A criterion was established

such that when yielding occurs throughout the thickness of the flange and about ½ the flange thickness in front of the crack, then a limit state is defined. Under these conditions, plastic ductile tearing will likely initiate rather than the fatigue cracking mechanism. The tensile load in the arm will then rapidly propagate the tearing until net section yield results.

This criteria means that the critical crack length or limit state is a function of the yield stress, the operating head, and the thickness reduction due to erosion-corrosion. For a given yield stress and operating head, the critical crack size will decrease as the corrosive environment reduces the thickness of the flange. Thus, a matrix of analyses was performed to find the crack length where the plasticity criteria is reached for variations of the three variables. For each combination of variables, a series of crack lengths are incorporated into the model, and the linear elastic stress distribution at the crack tip is evaluated with stress contour plots, as illustrated in Figure ED 5-28. When stresses greater than the yield stress are calculated throughout the flange thickness and for a region ahead of the crack, the corresponding crack length is established as the limit state for that combination of variables. An equation is then developed to relate the critical crack length to yield stress, operating head, and thickness reduction.

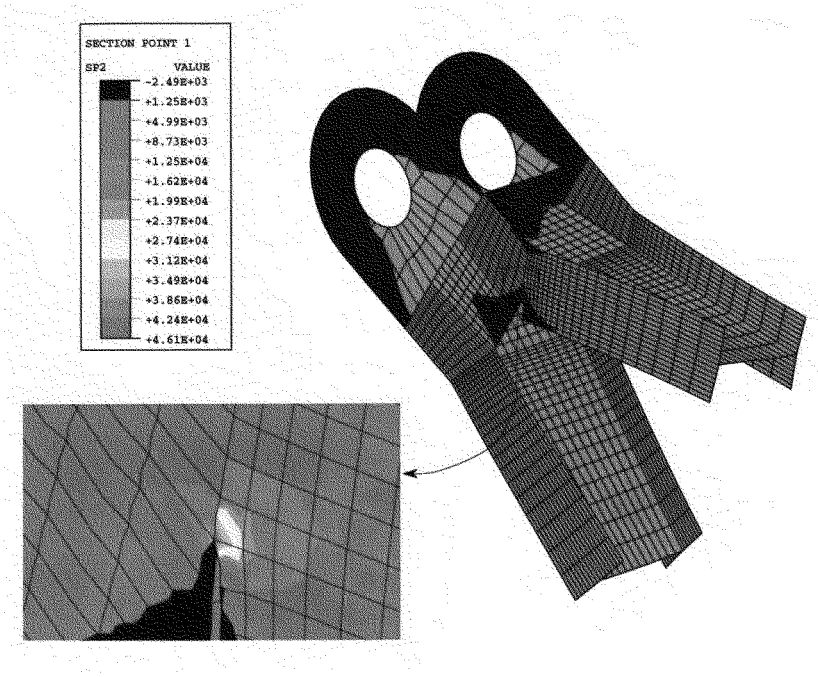


Figure ED 5-28. Linear Elastic Stress Distribution at Crack Tip

Finally, the influence of the hydrodynamic effects of the water impinging on the valve during the opening cycle must be addressed. This force will increase the loads in the structural components above the hydrostatic pressure head. For design, a "dynamic amplification load" of

1.5 to 2.0 times those due to the hydrostatic pressure is typically used. For the fatigue cracking reliability model, a realistic assessment must be determined in order to take any safety factors out of the analysis. As a method of determining this amplification factor on the operating head, a fluid flow analysis of the valve was conducted. The fluid flow calculation solves the Navier-Stokes equations for pressure gradients and fluid velocities using finite elements for the fluid filled regions. For this analysis, the valve was modeled as a smooth and rigid surface within the fluid flow region. Thus, no structural feedback is included. The fluid velocities and pressures are calculated for various gate open positions. The pressures calculated in the fluid at the gate surface are used to determine the likely factor for gate loads above the hydrostatic head applied in the structural calculations. Figure ED 5-29 illustrates the geometry, fluid velocities, and fluid pressure contours for this calculation. These calculations indicate a factor of 1.25 on the hydrostatic head is likely for hydrodynamic loads of opening the valve under a 30-ft. head differential.

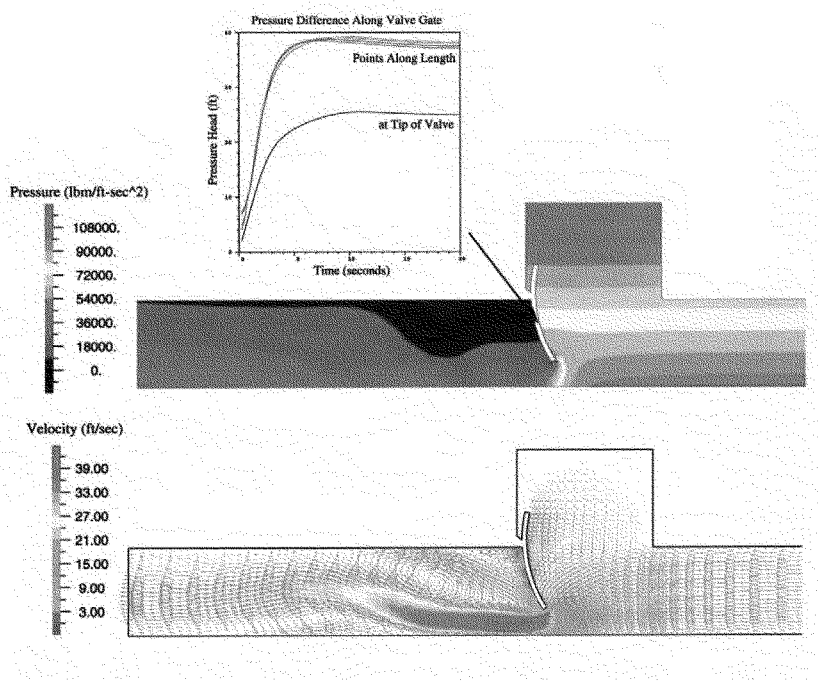


Figure ED 5-29. Fluid-Structure Interaction Diagrams and Contour Plots

5.4.5 Reliability Model Details

The reliability analysis for the horizontally-framed reverse tainter culvert valves was developed to measure the reliability associated with these type structures. In order to accomplish this effort, the team initially developed a spreadsheet model that investigated the typical analysis of the valves. The spreadsheet analysis included such items as fatigue associated with bending of the horizontal

beams that transfer load from the skin plate and also the bending of the main vertical girders. Additionally, axial force in the strut arms was checked over time with regard to fatigue and corrosion. The spreadsheet analysis showed no potential reliability problems with the valves *even after they would have been over 100 years old.* Neither the engineering team nor the operations personnel that work on the valves believed this to be an accurate representation of the reliability of the structure. This was due to the conservatism built into the design at the time of construction. However, it is known from reviewing operations records that repairs to the valves at all these Ohio River sites have caused significant chamber closures and costly repairs. Additionally, pitting and corrosion of the valves appears to be considerably greater for valves than other structures because of the turbulent water flowing across the structure associated with the opening and closing of the valve during chamber operation. Therefore, the engineering team decided that it would again be prudent to have a finite element analysis completed for the valves to investigate any potential problem areas. The engineering team decided to develop a Visual Basic coded model specifically for the ORMSS horizontally-framed reverse tainter culvert valves which was modeled after the one developed for the miter gates. The model was named HFCVWELD for horizontally-framed culvert valves. HFCVWELD was developed to investigate the reliability associated with the limit state described in Section 5.4.4 of this appendix.

HFCVWELD Reliability Model

The computer program HFCVWELD has been developed to complete a reliability analysis of the horizontally-framed culvert valves on the Ohio River system. The model was developed to measure the performance of the valves over time. Additionally, the model is used to determine if it is a better decision to replace the valves at some scheduled date as opposed to fixing them after they perform unsatisfactorily.

The basis of the model is that it is a time dependent reliability model for a structure subject to fatigue and corrosion. Therefore, input items such as paint history, corrosion rates, historical operating head with cycle information, and other variables are used in the model to determine the time dependent reliability of the structure.

Using the analysis and limit state information from the finite element modeling, HFCVWELD computes the time dependent reliability of the culvert valves given the input values. A critical crack length is input into the model as the limit state. For each iteration, the model determines the year in which a fatigue-related crack initiates and marks that year. Once the crack initiates, it is allowed to grow relative to the operating cycles within the histogram for each year after the time that it initiates. Once the crack reaches the limit state crack length, the year is tracked, recorded and marked as the year of unsatisfactory performance. This is done for each iteration and the results tabulated in a separate file.

The input menus associated with HFCVWELD look very similar to the ones for the miter gates. Input menus for things such as lock information, crack parameters, loading histograms, traffic cycles, etc. are input similar to the HWELD model for miter gates. In order not to repeat similar figures, please refer to the horizontally-framed miter gate model input narrative in Section 5.2.7 for figures depicting what the input menus look like.

1) Lock Information. The first portion of input is the project name and chamber that is being analyzed. For Markland and Greenup, the valves for both the main and auxiliary chambers are the same in terms of design and construction technique. However, operating cycles and age are different for the chambers and thus, each must be analyzed separately.

2) Crack Parameters. The initial crack length is set to a default value of 0.25 inches, the same as the miter gate initial crack length. The critical crack length is a function of other random

variables within the model and thus, is not input separately by the user. It is computed for each individual iteration within the model.

3) Head Histogram. The head histogram reflects the actual past distribution of head differential and hydraulic cycles for the reversed tainter valves. This distribution is based on true daily lockage cycles of each chamber available from the Lock Performance Monitoring System (LPMS) combined with the true head differential for each day. This distribution is very valuable in determining the fraction of annual cycles versus the expected head differential that can be used for fatigue analysis. The head histograms developed by WES are based on data collected and analyzed for approximately 12 years (1984–1995, inclusive) of lock operation. The HFCVWELD program allows the input of up to 20 different blocks for head (at specified midpoints) and fraction of cycles from the histograms. This histogram is used in HFCVWELD to parse the input annual cycles into the defined stress range blocks and number cycles for fatigue analysis.

4) Traffic Cycles. The number of operating cycles for the culvert valves are determined for each lock based on actual and predicted future cycles for the study period. The cycle information is used in fatigue analysis incorporated into the HFCVWELD program. The cycles are input from the start of operation to the end of the study period. Operating cycles from the origination of the each project through 1983 were determined by going through the log books to determine the number of lockages in each chamber. A ratio of lockages to operating cycles was determined and assumed to be the same in the past as well as for future projected cycles. Traffic cycles for 1984 through 2004 were determined on historical traffic using LPMS data. Future traffic projections for each of the five scenarios (Clear Skies, Modified Clear Skies, NAAQS, Utility Based, and Utility High) were provided by the ORMSS Economics Team.

Random Variables for HFCVWELD

The random variables incorporated into the HFCVWELD analysis are the yield strength of A36 steel, corrosion rate, residual stress factor, and the dynamic amplification factor. The values and ranges for the yield strength are the same as for the miter gates. The corrosion rate selected was for a structure subjected to wet/dry applications because the valves are constantly in and out of the water during operation. This rate is termed in the "splash" zone and has a higher corrosion rate than a submerged structure that was used for the miter gate analysis. Additionally, it was assumed that the valves only had an initial effective paint life of 5 years because of the turbulent water conditions impacting the valve during filling and emptying operations. This was based upon engineering judgment. However, sensitivity analyses were conducted varying the "effective" paint life from 0 to 20 years and it did not turn out to be a controlling variable. Therefore, the five-year life was used. Because a detailed residual stress analysis was not possible for this model due to funding and schedule constraints, a residual stress factor was created to attempt to measure the randomness associated with the residual stress analysis required for this model. The factor was based upon the residual stress analysis completed for the Markland miter gates. Finally, a dynamic amplification factor was needed to measure the increase in load on the valve due to the high velocities that occur during filling and emptying operations. This value (along with appropriate range) was determined by using a fluid flow analysis within the finite element model. This is described in Section 5.4.4. Again, all random variables were selected using Monte Carlo simulation.

1) Yield Strength. The distribution for yield strength is based on data from the published literature and previous Corps of Engineers reliability studies. The distribution is based on a truncated lognormal with a nominal yield stress of 38.88 ksi (i.e., mean yield strength times the

strength ratio) and a standard deviation of 5.44. The lower limit for truncation is based on one standard deviation below the nominal (33.44 ksi) and the upper limit is based on approximately two standard deviations above the nominal (51 ksi). The distribution and statistical moments for yield strength of the steel are the same as used for the miter gates.

2) Corrosion Rate. The distribution for corrosion is based on the data from the published literature ~~and previous Corps~~ of Engineers reliability studies. Corrosion is based on a power law that has been fit to actual field data in various corrosive environments. The equation used for the corrosion is $C(t) = A*t^B$, where A is a random variable based on field measurements, B is generally a constant based on different corrosive environments and C(t) is the corrosion in micromils/yr. For this report, the mean value of A was selected based on submerged corrosion. This distribution used for A was a truncated lognormal with a mean value was 140 and standard deviation of 42. The upper limit of the distribution was taken at 224 and the lower limit at 56. The value for B was a constant of 0.667. These limits and constants are based on actual field measurement of hydraulic steel structures.

3) Residual Stress and Dynamic Amplification Factors. Two types of factors are utilized in HFCVW~~ELD to account the major differences in stress values~~ between traditional hand calculations and the more sophisticated finite element analysis. The residual stress factor is for tensile stresses that are created during the heating and subsequent cooling of the welds at the time of construction. The second factor is the dynamic amplification factor, which represents increased load on the valve that is created by the vortex flow and pressure differential of the water around the valve upon opening. This quick change in pressure increases the stresses on the strut arms during valve operation. An extensive search for field measurement data on this subject was conducted, but did not turn up any definable results for forces on the valve. Therefore, these adjustment were determined based on a fluid flow finite element analysis to determine the range of values that may be exhibited in the valves.

The distribution for the residual stress model factors was considered to be normal since the limits were primarily defined as concentrated about a certain ratio. The mean value for residual stress was 0.35 with a standard deviation of 0.05. The dynamic amplification factor was determined to be a normal distribution with a mean of 1.25 (25% increase) and a standard deviation of 0.025 (2.5%).

5.4.6 HFCVWELD Reliability Model Results and Event Trees

The output from the HFCVWELD reliability model is an individual hazard function giving the overall probability of unsatisfactory performance of the culvert valve over time. The output is representative of a single valve at the project. Since the consequence event tree for the valves are developed around what response would be made if a single valve failed, then the overall reliability for all the culvert valves within the chamber need to be put in series. This will give the overall reliability for all four culvert valves within the main chamber. For the auxiliary chamber, this would require two valves being in series since there is only a single filling and single emptying valve. If historic repairs have been made to individual valves that improved the reliability performance, then the reliability of this individual valve was improved in the series system analysis.

MAIN CHAMBER HAZARD RATES AND EVENT TREE

Since there are several projects that have horizontally-framed culvert valves, the same type of process of selecting a single site as representative for the purposes of clearly describing the

process will be done for the valves. In order to depict different project features at different sites, the representative site for the horizontally-framed valves was selected as Greenup for the purposes of this narrative. As noted earlier, the HFCVWELD program produces a hazard rate for one valve per traffic projection. Three traffic projections (lowest, highest, and middle) are provided to the economists, along with a consequence event tree. Hazard rates for the valves were developed for the following traffic scenarios at Greenup: Clear Skies (lowest), Utility High (highest), and Modified Clear Skies (middle). A graphical representation of the calculated hazard rates for the main chamber valves at Greenup is shown in Figure ED-30.

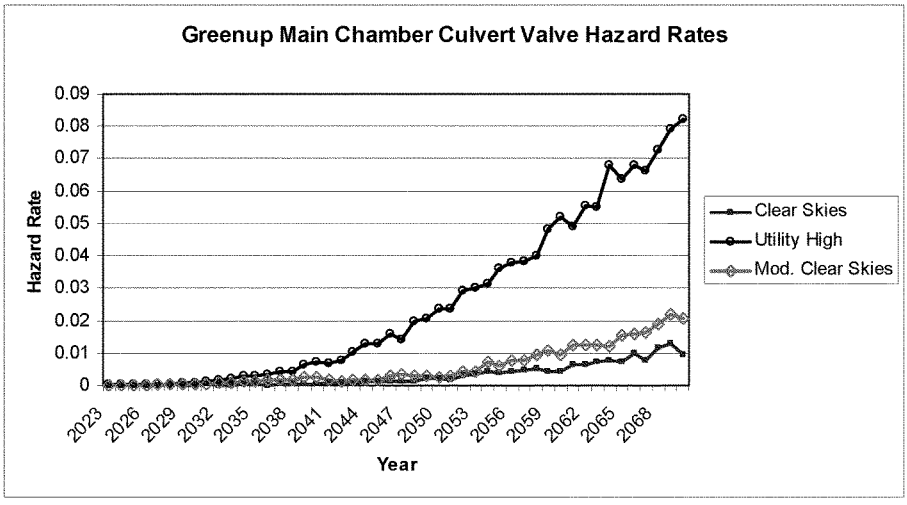
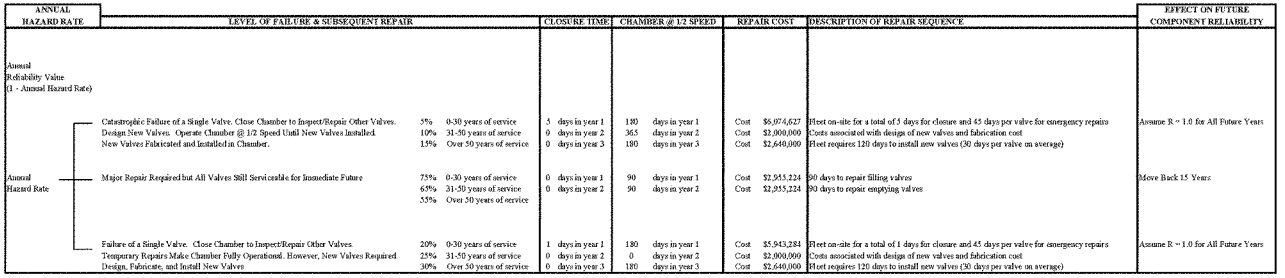


Figure ED 5-30. Greenup Main Chamber Culvert Valve Hazard Rates

The hazard rates shown in Figure ED 5-30 are for a single valve and were given to the economists along with chamber specific event trees. As illustrated in Figure ED 5-30, the Utility High forecast yields a hazard rate that is significantly higher than the middle (Modified Clear Skies) and low (Clear Skies) hazard rate. This is a function of the traffic forecast at Greenup. The event tree for the main chamber was formulated with the context of how historical repairs to valves have been made with the chamber operating at half filling/emptying speed. This is different than valve performance for Ohio River auxiliary chambers where there is only a single filling and single emptying valve used for the smaller 600-ft chamber. The doubling of filling and emptying time does not begin to compare to the navigation loss of benefits associated with having the main chamber closed and needing to move large tows through the smaller auxiliary chamber. Therefore, separate event trees were needed for the two chambers. The event tree for the main chamber is shown in Figure ED 5-31. A similar format as used for the miter gate event tree was used for the valves. Assuming an unsatisfactory performance of the culvert valve based upon the mode selected in the reliability model, three possible repair scenarios were chosen along with a replacement ahead of failure scenario which is used to time individual component replacements when economically justified. A breakdown of these repair scenarios for the main chamber culvert valves, along with their costs and closures are provided in Figure ED 5-31.



ANNUAL HAZARD RATE	LEVEL OF FAILURE & SUBSEQUENT REPAIR			CLOSURE TIME	CHAMBER @ 1/2 SPEED	REPAIR COST	DESCRIPTION OF REPAIR SEQUENCE	EFFECT ON FUTURE COMPONENT RELIABILITY
Annual Reliability Value (1 - Annual Hazard Rate)								
Annual Hazard Rate	Catastrophic Failure of a Single Valve. Close Chamber to Inspect/Repair Other Valves.	5%	0-30 years of service	5 days in year 1	180 days in year 1	Cost $6,974,627	Fleet on-site for a total of 5 days for closure and 45 days per valve for emergency repairs	Assume R = 1.0 for All Future Years
	Design New Valves. Operate Chamber @ 1/2 Speed Until New Valves Installed.	10%	31-50 years of service	0 days in year 2	365 days in year 2	Cost $2,000,000	Costs associated with design of new valves and fabrication cost	
	New Valves Fabricated and Installed in Chamber.	15%	Over 50 years of service	0 days in year 3	180 days in year 3	Cost $2,640,000	Fleet requires 120 days to install new valves (30 days per valve on average)	
Annual Hazard Rate	Major Repair Required but All Valves Still Serviceable for Immediate Future	75%	0-30 years of service	0 days in year 1	90 days in year 1	Cost $2,955,224	90 days to repair filling valves	Move Back 15 Years
		65%	31-50 years of service	0 days in year 2	90 days in year 2	Cost $2,955,224	90 days to repair emptying valves	
		55%	Over 50 years of service					
	Failure of a Single Valve. Close Chamber to Inspect/Repair Other Valves.	20%	0-30 years of service	1 days in year 1	180 days in year 1	Cost $5,943,284	Fleet on-site for a total of 1 days for closure and 45 days per valve for emergency repairs	Assume R = 1.0 for All Future Years
	Temporary Repairs Make Chamber Fully Operational. However, New Valves Required.	25%	31-50 years of service	0 days in year 2	0 days in year 2	Cost $2,000,099	Costs associated with design of new valves and fabrication cost	
	Design, Fabricate, and Install New Valves	30%	Over 50 years of service	0 days in year 3	180 days in year 3	Cost $2,640,000	Fleet requires 120 days to install new valves (30 days per valve on average)	

REPAIRS COST INFORMATION

$32,836	LRL Fleet Rate for Emergency Repairs to Valves (Factored Cost from ORMSS 1/2 Speed Historical Repair Work)
$200,000	Engineering Cost for Design of New Valves and Contract Award Effort (Markland Rehab Estimate)
$22,000	LRL Fleet Rate for Normal Valve Repairs (ORMSS Historical Database)
$1,800,000	Cost to Fabricate and Deliver 4 New Culvert Valves

REPLACEMENT OF MAIN CULVERT VALVES PRIOR TO FAILURE

Year 1 - Fabricate 2 Culvert Valves
Year 2 - Install 2 New Valves. Fabricate Other 2 Valves.
Year 3 - Install 2 Remaining Valves.

	Chamber 1/2 Speed	Cost of Repairs
Year 1	0	$900,000
Year 2	60	$2,220,000
Year 3	60	$1,320,000

There is no closure time required when valves are replaced ahead of failure.
With proper preparation, it will take about 30 days per valve to switch out the damage valve with the new one.

Figure ED 5-31. Main Chamber Culvert Valve Event Tree

Catastrophic Failure, Install 4 New Valves. This repair assumes the worst situation, a catastrophic failure of a culvert valve. It is assumed the damage and potential problems associated with the failure are enough to warrant a short closure of the main chamber to determine the problem and do a brief inspection of the other valves since they should all be of the same general condition. The duration of this closure is estimated to be 5 days and then the main chamber can be put back into service by operating at ½ speed. The overall repair effort is spread over 3 years since the damage caused by the failure is done during the first year and then four new valves are fabricated, delivered to the site and installed over the next two years. Future reliability is assumed to be equal to1.0 for the remainder of the study since new valves are installed. The repair cost associated with this repair is estimated at $10,714,660. The estimate is not accurate to that degree but the values are based upon average historical valve repair rates completed in the last 20 years by the Louisville District's repair fleet. There have been several emergency valve repairs made by LRL during this time frame and the average fleet rate for these repairs is $32,836 per day in FY05 dollars. The rate per day is lower because less personnel are required than full chamber dewaterings for miter gates where main chamber closure time must be kept to a minimum. It was also determined that a rate of approximately $22,000 per day is applicable for "normal" valve repairs from historic records. This rate will be used for work that can be planned in advance. A breakdown of the costs for this repair scenario is supplied below.

Repair Fleet Closes Chamber for 5 days for Inspection (Year 1):	$164,180 ($32,836/day for 5 days)
Full Inspection & Valve Repairs (45 days each valve, Year 1):	$5,910,480 ($32,836/day for 180 days)
Design, Fabricate and Delivery of 4 New Valves (Year 2):	$2,000,000
Installation of 4 New Valves in Chamber (Year 3):	$2,640,000 ($22,000k/day for 120 days)
Total for All Items for Catastrophic Repair:	**$10,714,660**

It is assumed that the chance of a catastrophic failure of this magnitude is quite low, therefore, it was decided to only place about a 5% chance of this occurrence in the first 30 years of service on this branch. This was increase to 10% for valves in service between 31 and 50 years, and finally, increased to a maximum of 15% for valve service life of over 50 years.

Temporary Repair with New Valves Following Year. This repair assumes that the major damage has occurred to at least one of the four valves such that it is out of service. The chamber is assumed to be shut down while engineers travel to the site to assess the situation. After a brief inspection, the chamber is opened back up for traffic but only at ½ speed while detailed inspection and repairs are made to all 4 valves. This would be done for each of the 4 valves. Emergency repairs would be made and then new valves would be designed and fabricated the following year. Installation of the 4 valves would occur in year 3 of the repair. Similar repair, fabrication, and installation times are assumed for this repair scenario as was done for the catastrophic repair. The only difference is the chamber is only closed 1 day in the year of the failure. The overall cost for this repair is estimated at $10,583,326 with chamber closure time of 1 day and total ½ speed time of roughly 2 years. Future reliability is assumed to be equal to 1.0 for the remainder of the study since new valves are installed the third and last year of this repair scenario. A breakdown of the costs for this repair is supplied below.

Repair Fleet Closes Chamber for 1 days for Inspection (Year 1):	$32,836 (emergency repair rate)
Full Inspection & Valve Repairs (45 days each valve, Year 1):	$5,910,480 ($32,836/day for 180 days)
Design, Fabricate and Delivery of 4 New Valves (Year 2):	$2,000,000
Installation of 4 New Valves in Chamber (Year 3):	$2,640,000 ($22,000/day for 120 days)
Total for All Items for Temporary Repair:	**$10,583,326**

It was agreed by the Engineering and Operations Team that this scenario was more likely to occur than the catastrophic repair scenario, however, it is not the most likely repair option. Thus, 20% was placed on this branch for up to 30 years of service, 25% between 31 and 50 years, and 30% for valves in service longer than 50 years. It is believed that the repair fleet would do everything possible to get the chamber operational again, however, major damage would prompt the district to obtain the funds to procure new valves.

Major Repair, Leave Existing Valves. This repair assumes the least damage to the culvert valves, such that they are repairable and can continue in service. For this situation, the main chamber does not require a closure, but is operated at ½ speed for repairs to each of the valves. It is estimated that each valve will require 45 days to repair. The cost associated with this alternative is estimated to be $5,910,480 over 2 years assuming a daily repair fleet rate of $32,836 per day for emergency valve repairs. It is assumed that the valves are repaired well enough that they can continue to provide adequate service in the future. Thus, the hazard rate after the repairs is lowered by "moving back" the hazard rate to a value to what it was 15 years prior to the failure and resetting the curve. Again, this is the easiest way to improve the reliability of a component after a repair in the economic model. A breakdown of costs associated with this repair is provided below.

Emergency Repairs to 2 Valves (45 days per valve, Year 1):	$2,955,240 ($32,836/day for 180 days)
Emergency Repairs to 2 Valves (45 days per valve, Year 2):	$2,955,240 ($32,836/day for 180 days)
Total for All Items for Major Repair:	**$5,910,480**

It was agreed that this scenario represented the most likely repair given the limit state modeled in the reliability analysis. Therefore, 75% was placed on this branch for valves with less than 30 years of service, 65% for valves with 31 to 50 years of service, and 55% for valves in service more than 50 years.

Scheduled Replacement of Culvert Valves. The other piece of information the economists need is the cost and chamber closure or filling/emptying effect associated with the scheduled replacement of the valves before failure. There are four valves for the main chamber and it can be operated at half-speed in the event of repair or replacement work to one of the valves. The simplifying assumption is made that new valves will be 100% reliable for this limit state for the remainder of the study period once they are installed. A well-planned and executed replacement should save considerable time when compared to the fix-as-fails scenarios evaluated with the hazard rate and event tree repair scenarios. Therefore, for this option is reduced to $4,440,000 and the total required time of the chamber operating at ½ speed is 120 days over a 2 year period. The cost and closure breakdown associated with a scheduled replacement of the main chamber culvert valves is provided below.

Fabrication of 2 New Valves (Year 1):	$900,000
Fabrication of Remaining 2 New Valves (Year 2):	$900,000
Installation of 2 New Valves (30 days per valve, Year 2):	$1,320,000 ($22,000/day for 60 days)
Installation of Remaining 2 New Valves (Year 3):	$1,320,000 ($22,000/day for 60 days)
Total for All Items for Replace Ahead of Failure:	**$4,440,000**

AUXILIARY CHAMBER HAZARD RATES AND EVENT TREE

As noted previously, the failure of a single culvert valve in a main chamber with 4 valves is considerably different that a failure of a single valve in an auxiliary chamber. The auxiliary

chambers on the Ohio River only have 2 valves (one filling and one emptying). Thus, a failure of an auxiliary chamber valve shuts that chamber down totally until the valve can be repaired. The same type of engineering reliability analysis is carried out for the auxiliary chamber culvert valves as was done for the main chamber culvert valves, however, chamber specific information such as operating cycles, paint history, etc. is applied to determine the hazard rate. Since the auxiliary chambers on the Ohio River are primarily used for recreational lockages and when the main chamber is closed for maintenance, they have seen significantly lower operating cycles to date. After conducting the engineering reliability analysis for the auxiliary chamber culvert valves, only one project (Markland) had enough operating cycles and stresses where predicted damage was high enough to generate a positive hazard rated during the study period. The analysis was carried out for the auxiliary chamber culvert valves, but no failures were encountered for the selected limit state. Since only one auxiliary chamber horizontally-framed culvert valve was analyzed in the economic analysis, no significant detail is provided on the event tree. However, the following general information applies. The same format was used, however, chamber closures were specified for each of the three levels of repair (catastrophic, temporary, and major) as opposed to ½ speed operating days for main chamber culvert valves. In addition, replacement costs are roughly ½ of the main chamber since there are only 2 valves for an auxiliary chamber.

5.4.7 Economic Results for Horizontally-Framed Culvert Valves

The Engineering Team provides both the hazard rates for the culvert valves, as shown in Figure ED 5-30 for Greenup, and the event tree shown in Figure ED 5-31 to the Economics Team for them to input into ORNIM. The other critical information for the main chamber culvert valves provided to the Economics Team was the replace ahead of failure costs and closures as outlined in Section 5.4.6 of this appendix. ORNIM was then used to compute average annual costs for two repair options (fix-as-fails or replace ahead of failure) for the main chamber culvert valves at Greenup. The average annual costs include both navigation delay and physical repair costs. Improved reliability after the repair is also included in the analysis, as noted in the event tree for differing levels of repairs. The costs of each alternative, fix-as-fails versus selected replacement dates, are compared to determine the most economic option. The replacement year with the lowest average annual cost sets the timed replacement of the culvert valves with fix-as-fails costs added to the economic analysis up to the year of scheduled replacement. Refer to the Economics Appendix for a more detailed description of how the ORNIM optimizes individual component replacements. If the lowest average annual cost is associated with the baseline condition (fix-as-fails), then the replacement of the culvert valves is not justified economically and the fix-as-fails costs are embedded into the overall economic analysis for every year of the study period. ORNIM produces a graphical output depicting the results and optimal timing of this process for each component and each traffic scenario. The ORNIM output for the Greenup main chamber culvert valves is shown for the Utility High traffic forecast in Figure ED-32.

As noted earlier, the culvert valves at Greenup were evaluated for each traffic scenario. Using the same methodology, optimized replacement dates were determined for each traffic scenario and are provided in the Economics Appendix.

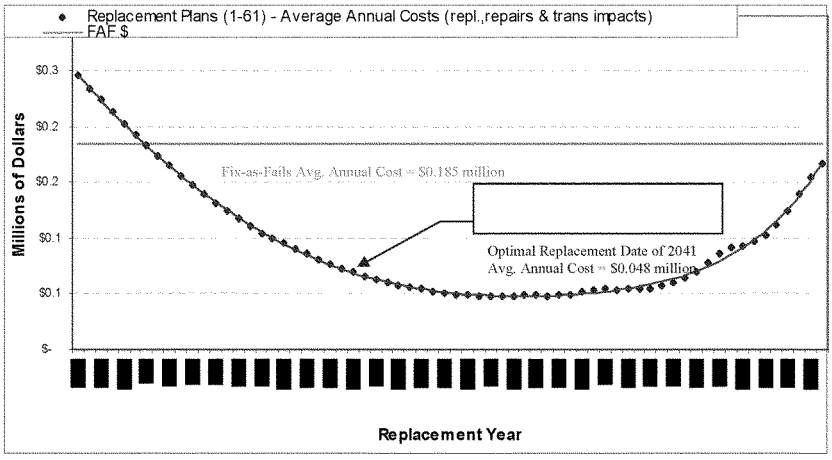


Figure ED 5-32. Greenup Main Culvert Valves Optimized Replacement Date (Utility High Traffic Scenario)

The lowest traffic scenario is the Clear Skies at Greenup. The other two lower scenarios, NAAQS and Modified Clear Skies, have only 12% and 13%, respectively, more cumulative projected traffic cycles between 2005 and 2070. However, the Utility Based and Utility High scenarios have 54% and 67%, respectively, more cumulative projected cycles than the Clear Skies scenario. For the culvert valves, this relates directly to the increased hazard rates for these traffic scenarios. This is more clearly depicted in Figure ED-30, which shows the hazard rates for the main chamber culvert valves at Greenup for the Clear Skies, Modified Clear Skies, and Utility High scenarios. The Utility High hazard rate is significantly higher than the other two scenarios in that graph. The much lower hazard rates combined with considerably less navigation delay consequences associated with operating at ½ speed compared to chamber closures is what causes the lower traffic projections to have "fix-as-fails" as the optimal economic solution for NAAQS, Modified Clear Skies, and the Clear Skies at Greenup.

Please refer to the tables in the Economics Appendix for the optimized replacement date of all horizontally-framed culvert valves across the Ohio River projects. These are given for each lock chamber by traffic scenario.

5.5 VERTICALLY-FRAMED REVERSE TAINTER CULVERT VALVE RELIABILITY

Reverse tainter culvert valves at Ohio River projects are used to control the filling and emptying of lock chambers. All sites with the exception of the upper three (Emsworth, Dashields, and Montgomery Locks and Dams) utilize reverse tainter culvert valves for the filling and emptying of the lock chamber. Emsworth, Dashields, and Montgomery (EDM) utilize butterfly valves for the operation of their filling and emptying systems. Butterfly valves are covered within the overall mechanical model. There are two types of reverse tainter culvert valves: horizontally-framed and vertically-framed. Separate reliability models had to be developed for each of these reverse tainter culvert valves. In general, the older sites use horizontally-framed culvert valves. These include the

valves at Pike Island, New Cumberland, Greenup, Meldahl, Markland, and the existing main chamber at McAlpine. The newer projects have vertically-framed valves. These sites include Willow Island, Belleville, Racine, Hannibal, R.C. Byrd, Cannelton, Newburgh, J.T. Myers, Smithland, and Olmsted. This section will focus on the horizontally-framed culvert valves. Section 5.4 focuses on horizontally-framed culvert valve reliability.

5.5.1 Main Chamber vs. Auxiliary Chamber

The same issues that apply main chamber versus auxiliary chambers for horizontally-framed culvert valves also apply to vertically-framed culvert valves on the Ohio River. There are 4 vertically-framed culvert valves for main chambers, the same as horizontally-framed culvert valves. Therefore, repairs can be made to vertically-framed valves while the lock continues to operate, although filling and emptying time is approximately doubled when compared to all valves operating properly. The auxiliary chambers on the Ohio River with vertically-framed valves are set up similar to the horizontally-framed culvert valves, two per auxiliary chamber. Thus, a repair to an auxiliary chamber vertically-framed valve requires a closure to the auxiliary chamber. However, the significance of closing the auxiliary chamber is considerably less than the main chamber where disbenefits associated with the closure can become large for extended closures.

5.5.2 Grouping of Vertically-Framed Reverse Tainter Culvert Valves

The valves are termed vertically-framed since the main load from the skin plate is transferred to large horizontal plate girders by a series of vertical curved ribs. The large horizontal plate girders transfer the load to a series of axially-loaded strut arms that connect the body of the valve to a pin plate casting, which transfers the load to the valve's trunnion beam. The trunnion beam then transfers the load to the concrete monolith. The valves act in tension since the tainter gate is reversed to the direction of flow. There are nine projects on the Ohio River system that utilize vertically-framed culvert valves. These valves can be broken into four separate groups. The groups are classified as follows:

Group 1. Group 1 vertically-framed culvert valves include those found at Willow Island, Belleville, Racine, and Hannibal Lock and Dams. These valves typically have curved vertical ribs that are approximately 11" deep and ½" thick. The flanges are roughly 6" wide and 1" thick. Most of the horizontal plate girders are 13 ½" deep by 1 ½" thick with flanges that measure 12" wide by 1 ¼" thick. Additionally, all four normally operate at a head of 20 to 22 feet.

Group 2. Sites considered for group 2 are Cannelton, Newburgh, and J.T. Myers. Each of these have vertical curved ribs that measure approximately 8" deep by ½" thick. The flanges typically measure 8" x 1". The horizontal girders measure approximately 28" deep by 5/8" thick. All these were built in the early 1970's.

Group 3. The valves at Smithland are the only ones in this group. This is mainly due to the small flange size on the vertical curved ribs. These ribs have flanges that measure only 4" wide by 1 ¼" thick. It should be noted that there was a major failure of one of the Smithland valves in 1998 at the connection of the vertical curved rib and lower horizontal girder. At the time of the failure, the other valves at Smithland were inspected and found to have the same deteriorated condition, thus, on the verge of failure.

Group 4. R.C. Byrd represents the only site with valves in this group. This is because the valves are the newest ones on the Ohio River system (1993) and do not fit well within other categories for member sizes.

Since all the vertically-framed valves on the Ohio River system are similar in construction type and operation, it was decided to develop the reliability model based upon field experience at Smithland. Therefore, global and local finite element models for the Smithland culvert valves were made in order to develop a time dependent reliability model for all Ohio River Mainstem Systems Study (ORMSS) vertically-framed valves. The limit state of the vertically-framed valves was centered around the type of failure that occurred at Smithland. From the Smithland global and local finite element models, appropriate adjustments were made to determine group specific load factors for such things as stress concentration factors associated with different member sizes.

Figure ED 5-33 shows the vertically-framed reverse tainter culvert valves being painted outside the chamber at Smithland. Note that all of the vertically-framed culvert valves are of similar general design and construction technique, thus, setting up the reliability model based upon experiences at Smithland is valid. Figures ED 5-34 through 5-38 depict the damage at Smithland from the 1998 failure and the limit state selected for the valves.

5.5.3 Finite Element Modeling and Calibration of Vertically-Framed Reverse Tainter Culvert Valves

Finite element modeling is used to develop reliability models for fatigue cracking at welded connections for vertically-framed culvert valves based on analyses and experience gained from reliability modeling for fatigue cracking at welded connections on miter gates and horizontally-framed culvert valves. In addition, recent field experience involving welded connection failures on a vertically framed culvert valves at the Smithland is used to guide the analysis and benchmark the reliability model. On each of these damaged culvert valves, the weld attaching a vertical rib to the main horizontal load beam failed, which separated the rib from the load beam. As the load transferred to adjacent connections, subsequent connections failed, both at the welded connections and from complete fracture through the vertical ribs.

This sequential failure at these connections is diagnosed to have progressed in a fairly rapid manner relative to a reliability study for fatigue cracking. Thus, once a crack initiated at the first welded connection, the operational failure of the valve developed within a relatively few additional cycles of operation. Therefore, for this reliability modeling, the limit state can be considered the initiation of fatigue cracking at the critical connection of the vertical rib to the horizontal load beam, and the finite element modeling concentrated on characterizing the fatigue failure of this connection.

A global model of half of the Smithland lock culvert valve, as illustrated in Figure ED 5-39, was developed to identify the local areas that are more susceptible to cracking due to elevated stress concentration factors. The Smithland design was used as a surrogate for the finite element modeling since field data was available for benchmarking and calibrating the reliability model. The global model indicated that the connection between the vertical rib and the horizontal load beam near the edge of the valve would develop the highest stress concentration under the normal operating head. This is the connection that was determined to have failed first in the Smithland culvert valve. More detailed modeling of this connection was then implemented into the global model, as illustrated in Figure ED 5-43, to characterize the fatigue cracking at this connection. At this type of connection, the top of the flange plate of the vertical rib is welded directly to the bottom of the flange plate on the horizontal load

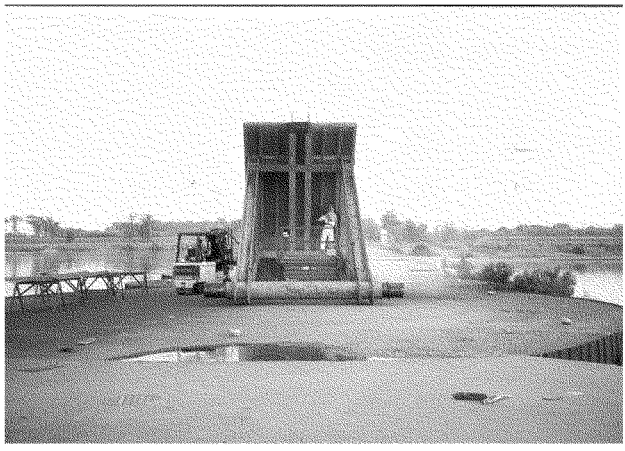


Figure ED 5-33. Photograph of Smithland Culvert Valve Being Painted

Figure ED 5-34. Side View of Failed Smithland Valve
Note sheared rib at strut arm and offset of curved ribs above and below horizontal girder.

Figure ED 5-35. Side View of Failed Curved Ribs at Bottom Horizontal Girder
Note the failure of the weld at horizontal girder in 2nd rib from end. Same weld failure occurred at 2nd rib from other end as well. All other ribs failed in shear.

Figure ED 5-36. Failure of Weld at 2nd Vertical Rib
Note weld material left on rib after it separated from horizontal girder.

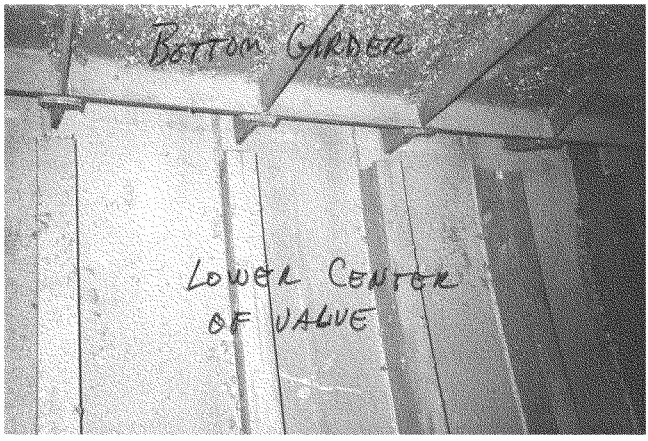


Figure ED 5-37. Shear Failure of Vertical Ribs in Middle of Valve
Note vertical rib on far right where initial weld failed.

Figure ED 5-38. Shear Failure and End Vertical Rib

beam using a fillet weld around the perimeter of the contacting plate areas. In the detailed modeling, the plate elements are constructed along the centerlines of the respective flanges. The two flanges are then connected together with plate elements around the perimeter representing the weld. The thickness of these weld elements is taken as the ligament thickness across the throat of the weld. The membrane stress in these weld elements, which acts through the depth of the weld, is used to establish the stress level for the fatigue cracking evaluations. Figure ED 5-40 also illustrates the maximum principal stress distribution in the weld at this connection due to the nominal operating head on the valve.

As in the reliability modeling for the horizontally framed culvert valves, a tensile residual stress is assumed to exist in the welded area. Because the connection failure is due to cracking along the weld, the residual stress can be assumed to be constant during the extension of the crack. This is consistent

with the field evidence that the fatigue crack extends relatively fast once it initiates. However, since limited funding and time constraints did not allow for detailed modeling of the distribution of residual

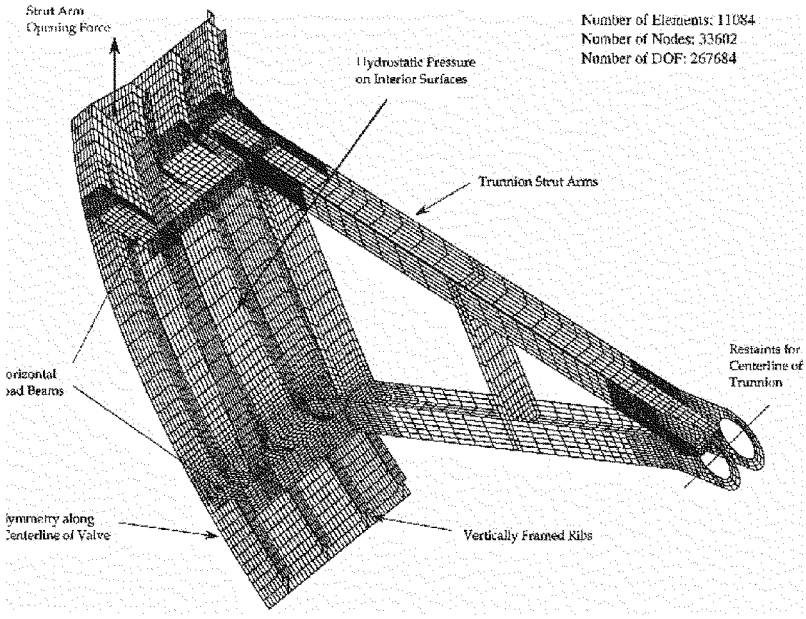


Figure ED 5-39. Global Finite Element Model of Smithland Culvert Valve

stresses, a larger variation for the level of residual stress is also assumed in the reliability calculations. The stress level calculated at the connection under the operational loads becomes the stress range for the fatigue cracking since these operational loads are imposed on top of the residual stresses. However, because the stress is cycling about a mean tensile value due to the residual stress, the effective alternating stress for determining the allowable fatigue cycles is adjusted using the Goodman relation.

The calculated peak membrane stress in the welded connection is used to establish a stress concentration factor that can be applied to the design based calculation for the average stress in the weld. The flange sizes are adjusted in the global model to account for the differences between site-specific culvert valve designs. For example, Figure ED 5-41 shows the principal stress contours for the geometry of Ohio River main chamber culvert valves (J.T. Myers is shown as an example in the Figure) to illustrate the stress concentrations present through the depth of the weld material. The stress concentration is then characterized for variations in operating head and thickness reduction due to corrosion.

The dynamic amplification factor of 1.3 on the nominal pressure head is also used to account for the hydrodynamic loading during opening of the valve. This factor was developed based on fluid flow modeling for a horizontally-framed culvert valve. Since this effect is a function of the general shape of the valve and culvert, rather than the details of the construction, this factor is also used for the vertically-framed culvert valve reliability model. For further details regarding the fluid-flow interaction, please refer to the horizontally-framed culvert valve narrative in Section 5.4 of this

appendix. Figure ED 5-42 illustrates the principal stress for crack initiation characterized as a function of head and thickness reduction developed for the reliability model.

As mentioned previously, the limit state of the vertically-framed culvert valve is defined to be the initiation of fatigue cracking at the welded connection between the vertical rib and the horizontal load beam. Field experience indicates that this cracking will rapidly propagate due to the reduction in area resisting the cyclic tensile loads. The cracking will completely separate the vertical rib from the horizontal load beam. As the load is transferred to the adjacent connections, similar failures will propagate until the valve has an operational failure. The failure hazard due to this limit state was benchmarked successfully with the Smithland and field experience. Thus, for this reliability modeling, the initiation of fatigue cracking at the first connection is considered sufficient to establish a failure of the valve.

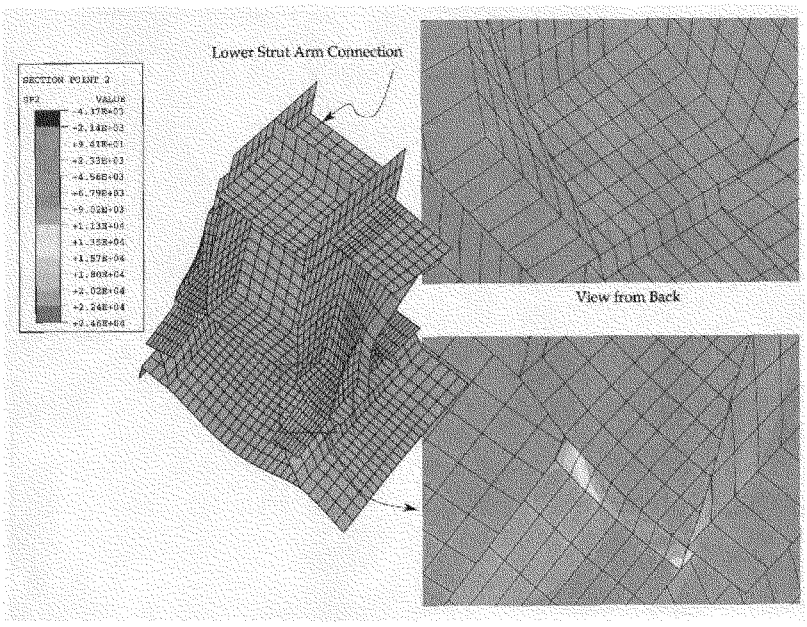


Figure ED 5-40. Maximum Principal Membrane Stress Refined Modeling of Welded Connection

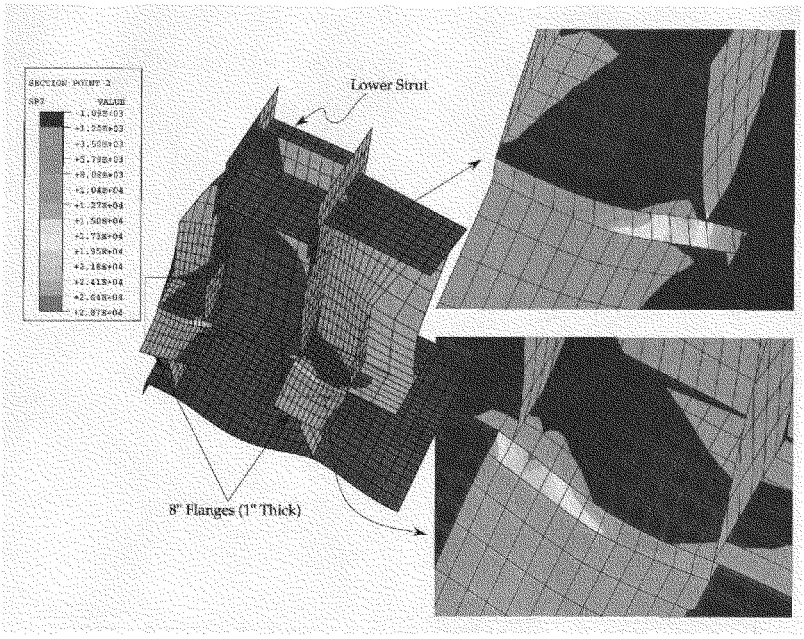


Figure ED 5-41. Maximum Principal Membrane Stress at Welded Connections for Ohio River Main Chamber Culvert Valves

5.5.4 Reliability Model Parameters

The time-dependent reliability analysis for the vertically-framed reverse tainter culvert valves was developed to estimate the hazard rate for these structures. Similar to the miter gate and horizontally-framed valve reliability models, the reliability analysis for vertically-framed valves incorporates both the fatigue and corrosion of the welds at the girder/rib connections of the valves. Additionally, the engineering team performed a range of 3-D finite element analyses of the valves to investigate the potential modes of failure of the valve, redistribution of loads upon failure, and the realistic values of stresses (both residual, static, and dynamic) to utilize into the reliability model. The limit state incorporated into the reliability model is based on the initiation of a crack at the girder/rib weld interface that causes a failure of the welds at the rib, which causes a redistribution of loads to the welds at the adjacent ribs. As evidenced from the valves at Smithland, actual field experience was used in the modeling effort to calibrate the timing of the limit state for the valves. For this model, the engineering team decided to develop a Visual Basic coded model specifically for the ORMSS vertically-framed reverse tainter culvert valves which was modeled similar to one developed for the miter gates and horizontally-framed culvert valves. The Visual Basic model was named VFCVWELD for the reliability of vertically-framed reverse tainter culvert valves.

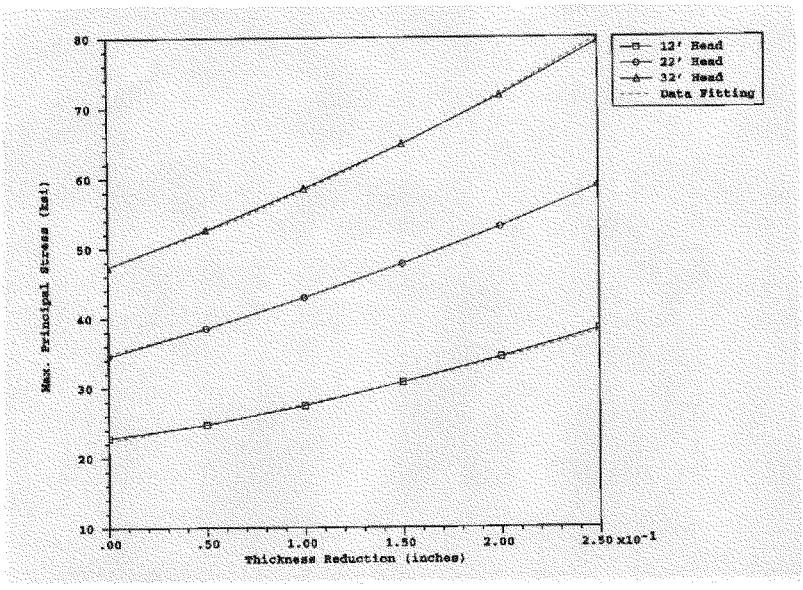


Figure ED 5-42. Principal Stress at Welded Connection as Function of Head and Thickness Reduction Due to Corrosion

VFCVWELD Reliability Model

The computer program VFCVWELD has been developed to complete a reliability analysis of the vertically-framed culvert valves for ORMSS lock projects. The model was developed to measure the future performance of the valves over time relative to the selected limit state. Additionally, the model is used to determine if it is a better decision to replace the valves at some scheduled date as opposed to fixing them after they perform unsatisfactorily.

The basis of the model is to determine the time dependent reliability for the valve structure subjected to fatigue and corrosion. Therefore, input items such as paint history, corrosion rates, historical operating head with cycle information, and other random variables are used in the model to determine the time dependent reliability of the structure. Using the analysis and limit state information defined from the finite element modeling, VFCVWELD computes the time dependent reliability of the vertically-framed culvert valves given the input parameters. For each iteration, the model determines the year in which a fatigue-related crack initiates and marks that year as the time of unsatisfactory performance. This is done for each iteration and the results are tabulated for the hazard function in a separate file.

Lock Information. The first portion of input is the project name and chamber that is being analyzed. For each of the ORMSS locks, both the main chamber and auxiliary chamber valves are of the same design and construction technique. However, operating cycles and age are different for the chambers and thus, each must be analyzed separately. The input menu from VFCVWELD for the lock information is to specify the district, lock project, and chamber that is being analyzed.

Rib/Girder Properties. The VFCVWELD program requires the input of rib and girder properties for the valve. Since the original model was calibrated to the performance at Smithland, most of the figures will reference Smithland vertically-framed valve properties. The input menu for the valve properties includes the vertical spacing between ribs, the length of the valve, the top dimension distance to the horizontal girder which defines the positions of both the top and bottom girders on the vertical ribs (for simplicity, the top and bottom ribs were assumed to be equidistant from both ends since all differences are very minor), the rib flange width, the horizontal girder flange width, and finally both the horizontal and vertical weld thickness at the rib/flange connection. The input for these properties in VFCVWELD for the Smithland valves are shown in Figure ED 5-43.

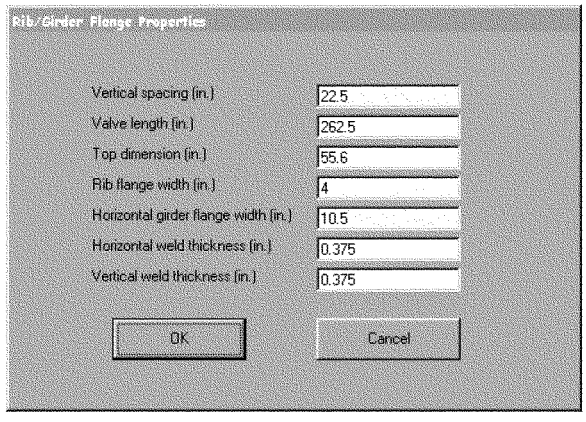


Figure ED 5-43. Rib/Girder Flange Properties Input Menu

Crack Parameters. The only crack parameter required for the VFCVWELD is the initital crack length. This is because the reliaibility model only accounts for the crack initiation and not crack propogation because of the anticipated brittle failure mode that was evidenced at Smithland. The initial crack length is set to a default value of 0.25 inches, the same as the miter gate initial crack length.

Head Histogram. The head histogram reflects the actual past distribution of head differential and hydraulic cycles for the reverse tainter valves. This distribution is based on true daily lockage cycles available from the Lock Performance Monitoring System (LPMS) combined with the true head differential for each day. This distribution is very valuable in determining the fraction of annual cycles versus the expected head differential that can be used for fatigue analysis. The head histograms developed by WES are based on data collected and analyzed for approximately 21 years inclusive (1984–2004) of lock operation. The VFCVWELD program allows the input of up to 20 different blocks for head (at specified midpoints) and fraction of cycles from the histograms. This histogram is used in VFCVWELD to parse the input annual cycles into the defined stress range blocks and number cycles for fatigue analysis. An example head histogram is shown in Figure ED 5-44 for Markland Lock and Dam (even though Markland valves are horizontally-framed, the histograms are similar in nature).

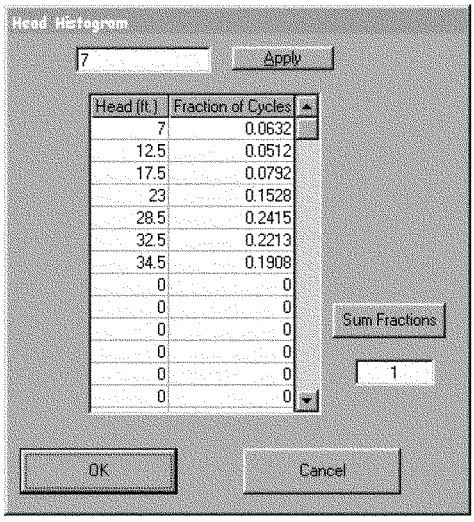


Figure ED 5-44. Example of Head Histogram

Traffic Cycles. The number of operating cycles for the vertically-framed valves is determined for each lock based on actual and predicted future cycles for the study period. The cycle information is used in fatigue analysis incorporated into the VFCVWELD program. The cycles are input from the start of operation to the end of the study period. Operating cycles from the origination of the project through 1984 were determined by going through the log books at various ORMSS sites to determine the number of lockages in each chamber. From the LPMS data from 1984 through 2004, a ratio of lockages to operating cycles was determined and assumed to be the same in the past as well as for future projected cycles. Traffic cycles for 1985 through 2004 were determined using LPMS data. Finally, projected traffic through the end of the study period was determined by LRD's Navigation Center in Huntington, WV. The input traffic cycles for one of the Smithland 1200-ft chambers are shown in Figure ED 5-45.

Random Variables Used in VFCVWELD

The random variables incorporated into the VFCVWELD analysis are the yield strength of A36 steel, corrosion rate, residual stress factor, stress concentration factor, and the dynamic amplification factor. The values and ranges for the yield strength used for the vertically-framed valve analysis are the same as applied to the miter gates and horizontally-framed culvert valves. The corrosion rate selected was for a structure subjected to wet/dry applications because the valves are constantly in and out of the water during operation, again the same as the horizontally-framed culvert valves. This rate is termed in the "splash" zone

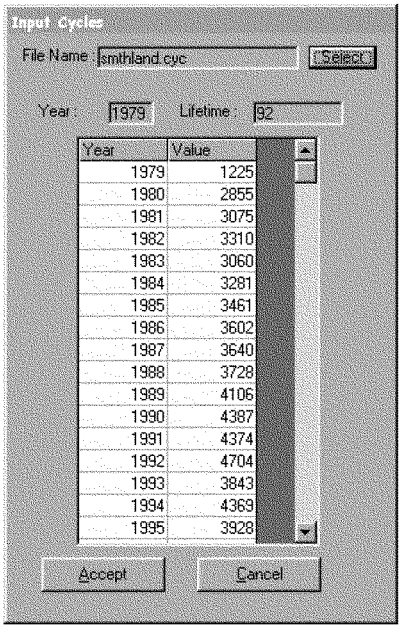


Figure ED 5-45. Example Input Traffic Cycles

and has a higher corrosion rate than a submerged structure. Additionally, it was assumed that the valves only had an initial effective paint life of 5 years because of the turbulent water conditions impacting the valve during filling and emptying operations. This was based upon engineering judgment. However, sensitivity analyses were conducted varying the "effective" paint life from 0 to 20 years and it did not turn out to be a controlling variable. Therefore, the five-year life was used to be consistent with the analysis for the horizontally-framed culvert valves. Because a detailed residual stress analysis was not possible for this model due to funding and schedule constraints, a residual stress factor and stress concentration factor was created to attempt to measure the randomness associated with the residual stress analysis required for this model. The factor was based upon the residual stress analysis completed for the Markland miter gates. This is also consistent with the analysis for the horizontally-framed culvert valves. Finally, a dynamic amplification factor was needed to measure the increase in load on the valve due to the high velocities that occur during filling and emptying operations. This value (along with appropriate range) was determined by using a steady state fluid-structure interaction finite element model. This model is described in the horizontally-framed valve narrative. Again, all random variables were selected using Monte Carlo simulation techniques.

Yield Strength. The distribution for yield strength is based on data from the published literature and previous Corps of Engineers reliability studies. The distribution is based on a truncated lognormal with a nominal yield stress of 38.88 ksi (i.e., mean yield strength times the strength ratio) and a standard deviation of 5.44. The lower limit for truncation is based on one standard deviation below the nominal (33.44 ksi) and the upper limit is based on approximately two standard deviations above the nominal (51 ksi). The distribution and statistical moments for yield strength of the steel are the same as used for the miter gates and horizontally-framed culvert valves.

Corrosion Rate. The distribution for corrosion is based on the data from the published literature and previous Corps of Engineers reliability studies. Corrosion is based on a power law that has been fit to actual field data in various corrosive environments. The equation used for the corrosion is $C(t) = A*t^B$, where A is a random variable based on field measurements, B is generally a constant based on different corrosive environments and C(t) is the corrosion in micromils/yr. For this report, the mean value of A was selected based on "splash zone" corrosion. This distribution used for A was a truncated lognormal with a mean value was 140 and standard deviation of 42. The upper limit of the distribution was taken at 224 and the lower limit at 56. The value for B was a constant of 0.667. These limits and constants are based on actual field measurement of hydraulic steel structures.

Residual Stress, Stress Concentration, and Dynamic Amplification Factors. Three types of factors are utilized in VFCVWELD to account the major differences in stress values between traditional hand calculations and the more sophisticated finite element analysis. The residual stress factor represents the tensile stresses that are created during the heating and subsequent cooling of the welds at the time of construction. The second factor is the dynamic amplification factor, which represents increased load on the valve that is created by the vortex flow and pressure differential of the water around the valve upon opening. This quick change in pressure increases the stresses on the strut arms during valve operation. The third factor is the stress concentration factor that tries to account for local stress increases to due fabrication confinements that occur in welded structures. An extensive literature search for field measurement data on these factors was conducted. No data is available to assist in better defining any these parameters for the reliability of the valve. Therefore, these adjustments were determined based on various finite element analysis to determine the range of values that may be exhibited in these random variables.

The distribution for the residual stress model factors was considered to be a Gaussian distribution since the limits were defined by a concentration about a certain percent ratio. The mean value for the residual stress was 0.35 with a standard deviation of 0.05. The dynamic amplification factor was also determined to be a normal distribution with a mean of 1.25 (25% increase) and a standard deviation of 0.025 (2.5%). As an example, the stress concentration factor for the Group 2 valves was determined to be a uniform distribution with an upper limit of 2.1 and a lower limit of 1.5.

5.5.5 VFCVWELD Reliability Model Results and Event Trees

The output from the VFCVWELD reliability model is a hazard function giving the annual probability of unsatisfactory performance of the culvert valve over time. For simplicity, it was decided to look only at the reliability associated with a single valve as compared to numerous ones for the main chamber. The consequence event tree is structured around the failure of a single valve and how repairs would be initiated following a valve failure.

Main Chamber Results and Event Tree

Similar to other sections, a single project site (Cannelton in this case) will be detailed to clearly illustrate the process of modeling carried out for vertically-framed culvert valves and the subsequent output. As an example of the output provided by the VFCVWELD program, the hazard rates for the vertically-framed culvert valves of the Cannelton main chamber are shown in Figure ED 5-46 for the high (NAAQS), middle (Utility High) and low (Clear Skies) future traffic projections. As shown in Figure ED 5-46, the variability between the hazard rates for the main chamber vertically-framed culvert valves does not vary greatly. This is primarily due to the fact that the cumulative future traffic cycles are fairly similar across all traffic scenarios, unlike the large difference between the utility-based scenarios and the other three scenarios at Greenup. This was detailed in the horizontally-framed

culvert valve reliability analysis in Section 5.4 of this appendix. For example, at Cannelton the difference between the lowest traffic scenario (Clear Skies) cumulative traffic cycles and the highest scenario (NAAQS) was roughly 23%. However, at Greenup this difference was 67% between the lowest and highest. This relative difference is directly related to the hazard functions for the culvert valves.

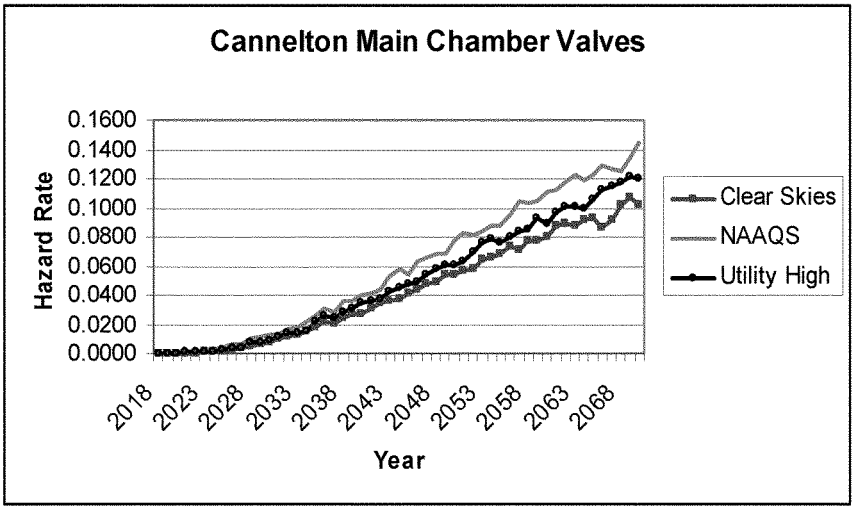


Figure ED 5-46. Cannelton Vertically-Framed Culvert Valve Hazard Rates

5.5.6 Economic Results for Vertically-Framed Culvert Valves

The hazard rates shown in Figure ED 5-46 are combined with consequence event trees for the vertically-framed culvert valves. It is important to note that the same event trees for the main chamber vertically-framed culvert valves are applicable for the horizontally-framed culvert valves. Although there are structural differences between the two types of valves, they are not great enough to warrant using different event trees. The details associated with the event trees for culvert valves, both main and auxiliary chambers, are described in Section 5.4.6 of this appendix.

ORNIM was then used to compute average annual costs for two repair options (fix-as-fails or replace ahead of failure) for the main chamber culvert valves at Cannelton. The average annual costs include both navigation delay and physical repair costs. Improved reliability after the repair is also included in the analysis, as noted in the event tree for differing levels of repairs. The costs of each alternative, fix-as-fails versus selected replacement dates, are compared to determine the most economic option. The replacement year with the lowest average annual cost sets the timed replacement of the culvert valves with fix-as-fails costs added to the economic analysis up to the year of scheduled replacement. Refer to the Economics Appendix for a more detailed description of how the ORNIM optimizes individual component replacements. If the lowest average annual cost is associated with the baseline condition (fix-as-fails), then the replacement of the culvert valves is not justified economically and the fix-as-fails costs are embedded into the overall economic analysis for

every year of the study period. ORNIM produces a graphical output depicting the results and optimal timing of this process for each component and each traffic scenario. The ORNIM output for the Cannelton main chamber culvert valves is shown for the Utility High traffic forecast in Figure ED 5-47.

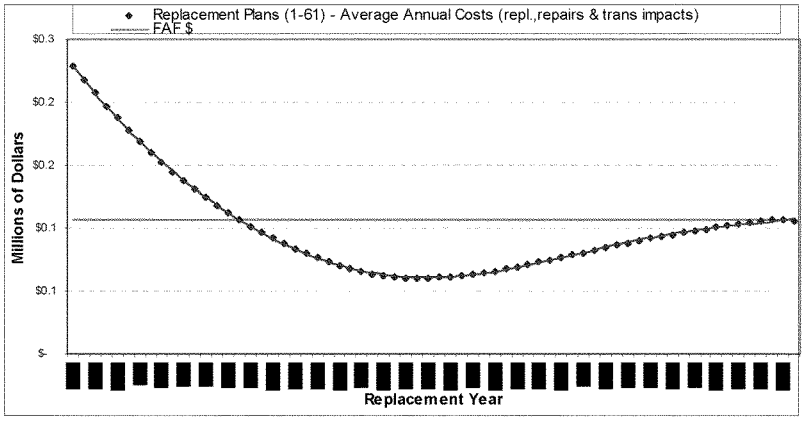


Figure ED 5-47. Economic Results for Cannelton Main Valves for Utility High Forecast

As noted earlier, the culvert valves at Cannelton were evaluated for each traffic scenario. Using the same methodology, optimized replacement dates were determined for each traffic scenario. The projected replacement dates for each traffic scenario are provided in the Economics Appendix.

As shown in Figure ED 5-46, there is a relatively small difference in the hazard rates between all three traffic scenarios for the main chamber culvert valves at Cannelton. Thus, the replacement dates only will vary slightly across the different traffic projections for this particular component.

Please refer to the tables in the Economics Appendix for the optimized replacement date of all vertically-framed culvert valves across the Ohio River projects. These are given for each lock chamber by traffic scenario.

5.6 ELECTRICAL SYSTEM RELIABILITY FOR THE LOCK

The electrical system for the lock essentially is made up of a series of individual components that work in series and parallel to operate the lock. Included in this list of components are items like commercial power source, diesel generator, fuses, motors, controllers, solenoids, etc. The electrical model was kept a single model in that the team decided not to try to develop separate hazard rates for each specific component. Since the vast majority of the system operates in series, a failure of any single item, with the exception of the possibly the commercial power supply or a diesel generator, would shut the lock down until repairs were made. Therefore, a single overall lock model was set up for the development of one hazard rate per lock chamber with a single event tree to reflect failures and repairs.

Many of the lock electrical systems are set up with similar systems. There are various changes to the lock electrical system as different pieces are parallel and in series from one project to another. These changes make each lock electrical model unique. The other thing that makes each unique is that

each lock chamber sees a different number of operating cycles each year. This section of the Engineering Appendix will discuss the lock electrical reliability model in a general nature to give the reader a feel of how the model is set up and calibrated versus field conditions.

5.6.1 Assessment of Reliability for Electrical System of the Lock

The electrical reliability assessment is based in principle on procedures defined by ETL 1110-2-549, Engineering and Design, RELIABILITY ANALYSIS OF NAVIGATIONAL LOCK AND DAM MECHANICAL AND ELECTRICAL EQUIPMENT. However, it should be noted that the failure rates and other relevant information listed in the ETL is for electrical equipment is not necessarily from locks and dams. Therefore, careful consideration was given when using select failure rates and other information from this ETL. Calibration with field conditions was used to the best extent possible. The following paragraphs document the assumptions, current conditions and provide the results of the reliability assessment.

5.6.2 Component Condition Investigations

For the purposes of this report, the lock electrical systems at Newburgh will be detailed to show how the electrical model was set up and developed for each project. Newburgh has two locks, a main, 1200-ft. lock, and an auxiliary, 600-ft. lock, which is typical for most Ohio River projects. Newburgh became operational in 1974. Each lock has four miter gates that are operated by hydraulically driven sector gears. The electrical power is provided by the local utility, with backup power provided by a diesel generator. Most of the electrical equipment, excepting that replaced during regular maintenance, is the original equipment at both projects. This is similar to all other projects except EDM, which had the electrical systems upgraded as part of major rehabilitation projects in the mid to late 1980's. The lock electrical systems at EDM are considered new with the major rehabilitation projects.

5.6.3 Condition States of the Electrical System

The reliability, R(t), for each component and for the system as a whole, was calculated for every year of operation from installation through the year 2070. The limit state was defined as the Mean Time to Failure (MTF) for the expected useful life of the components being analyzed. The hazard rate of any system is defined by the following relationship to be the probability of unsatisfactory performance, provided the component or system has not failed until the time of assessment: $h(t) = f(t)/R(t)$. The general reliability block diagram and one-line of the basic electrical system for Newburgh is shown in Figure ED 5-48.

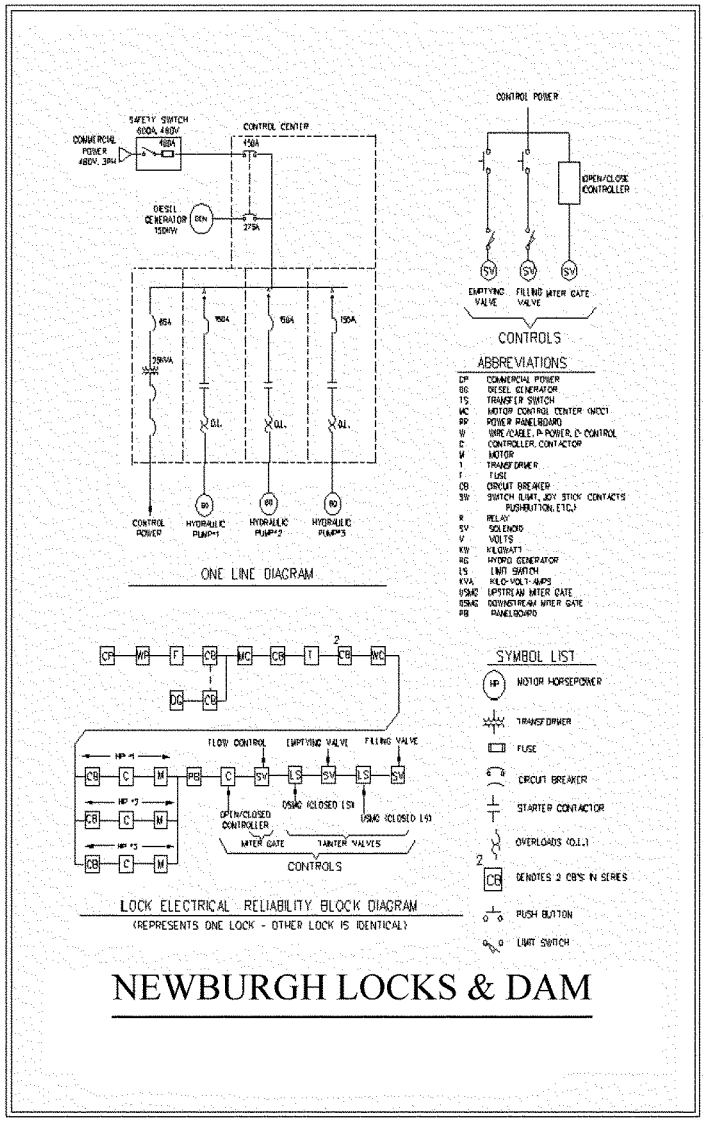


Figure ED 5-48. Newburgh One Line Diagram for Lock Electrical System

5.6.4 Failure Rate of Electrical Components

The environmental conditions were considered for the ambient service of the electrical equipment. Lambda, λ, represents the number of failures per 1 x 10^6 operating hours. The values were based on data from equipment similar in nature, but not necessarily associated with locks and dams. Therefore, the failure rates of all applicable equipment were based on available data and engineering judgment based on repair history. Also, the length of time parts are generally readily available for a given serviceable component also figured into failure rates for electrical components.

5.6.5 Failure Types

In this analysis, electrical equipment comes to the end of its "useful life" by one of three types of failures. These are termed the *Duty Cycle Failure, Environmental Conditions/Entropy*, and *Obsolescence*. Each is described within this sub-section.

Duty Cycle Failure

This type of failure is based on the amount of time that the component is operated or how many cycles it has to go through multiplied by the time per cycle. Since the equipment does not operate continually, the total mission time is determined with a duty cycle factor. The duty cycle factor is the ratio of actual time the equipment is energized by voltage and/or current to the total mission time, t. The example from ETL 1110-2-549 states that the equation $R(t) = e^{-\lambda td}$ is a constant failure rate component with a duty factor d. The lock equipment in the example had an average number of 13,148 open/close cycles per year. Assuming the operating time of an open/close operation is 120 seconds (or 240 seconds per open/close cycle) and using a total mission time of equal to the study period for the economic analysis, which happens to be 50 years in this example. Therefore, the calculation is as follows for a 50-year study period:

Operating time = (240*13,148)/3600
= (877 operational hours/year)*(50 years)
= 43,850 hours = 5 years

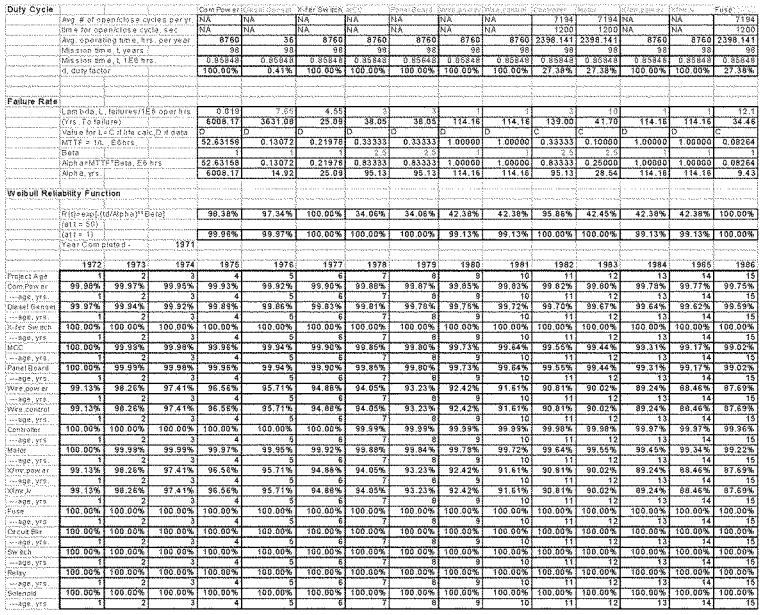
For t = 50 years,

d = 5/50 = 0.10

This analysis uses the past and projected cycles as a key input to this analysis. To determine the duty cycles for each component, see Figure ED 5-49, which shows some of the model computations for the main chamber electrical system for Newburgh. The first page of the model for Newburgh main chamber is provided in this report only since all the computation sheets are similar for all projects. The total number of cycles for each lock is divided by the total number of years of operation to come up with the average cycles per year. Electrical equipment, which is normally energized 100% of the calendar year, has a duty cycle of 1.0.

Environmental Conditions and Entropy

This type of failure relates to components such as a wire, which has insulation that degrades over time, whether it has current flow or not. In this case, historic replacement information is used. For example, several locks have installed new wiring after approximately 50 years of operation. While this replacement was more of a preventative measure than a repaired failure, it does define the "useful



Duty Cycle		Com Power	Diesel Genset	Kifer Switch, ATS	Panel Board	Seepage Pump Motor Starter	Controller	Motor	Wire power	Others	Fuse
	Avg. # of open/close cycles per yr.	NA	NA	NA	NA	NA	NA	7194	7194	NA	7194
	time for open/close cycle, sec	NA	NA	NA	NA	NA	NA	1200	1200	NA	1200
	Avg. operating time, hrs. per year	8760	36	8760	8760	8760	8760	2398.141	2398.141	8760	2398.141
	Mission time, t, years	98	98	98	98	98	98	98	98	98	98
	Mission time, t, 1E6 hrs	0.85848	0.85848	0.85848	0.85848	0.85848	0.85848	0.85848	0.85848	0.85848	0.85848
	d, duty factor	100.00%	0.41%	100.00%	100.00%	100.00%	100.00%	100.00%	27.38%	27.38%	100.00%	100.00%	27.38%
Failure Rate											
	Lambda, L, failures/1E6 oper hrs	0.019	7.85	4.55	3	3	1	3	10	1	12.1
	(Yrs. To failure)	6008.17	3631.08	25.09	38.05	38.05	114.16	114.16	139.00	41.70	114.16	114.16	34.46
	Value for L-C life calc, D if data	D	D	D	D	D	D	D	C	C	D	D	C
	MTTF = 1/L, E6hrs	52.63158	0.13072	0.21978	0.33333	0.33333	1.00000	1.00000	0.33333	0.10000	1.00000	1.00000	0.08264
	Beta	1	1	1	2.5	2.5	1	1	2.5	2.5	1	1	1
	Alpha=MTTF^Beta, E6 hrs	52.63158	0.13072	0.21978	0.83333	0.83333	1.00000	1.00000	0.83333	0.25000	1.00000	1.00000	0.08264
	Alpha, yrs	6008.17	14.92	25.09	95.13	95.13	114.16	114.16	95.13	28.54	114.16	114.16	9.43
Weibull Reliability Function											
	R(t)=exp[-(t/Alpha)^Beta]	98.38%	97.34%	100.00%	34.06%	34.06%	42.38%	42.38%	95.86%	42.45%	42.38%	42.38%	100.00%
	(at t = 50)												
	(at t = 1)	99.98%	99.97%	100.00%	100.00%	100.00%	99.13%	99.13%	100.00%	100.00%	99.13%	99.13%	100.00%
	Year Completed -	1971											

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Project Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Com Power	99.98%	99.97%	99.95%	99.93%	99.92%	99.90%	99.88%	99.87%	99.85%	99.83%	99.82%	99.80%	99.78%	99.77%	99.75%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diesel Genset	99.97%	99.94%	99.92%	99.89%	99.86%	99.83%	99.81%	99.78%	99.75%	99.72%	99.70%	99.67%	99.64%	99.62%	99.59%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kifer Switch	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MCC	100.00%	99.99%	99.99%	99.96%	99.94%	99.90%	99.86%	99.80%	99.73%	99.64%	99.55%	99.44%	99.31%	99.17%	99.02%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Panel Board	100.00%	99.99%	99.99%	99.96%	99.94%	99.90%	99.86%	99.80%	99.73%	99.64%	99.55%	99.44%	99.31%	99.17%	99.02%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Wire power	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Wire control	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Controller	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	99.99%	99.99%	99.99%	99.99%	99.98%	99.98%	99.97%	99.97%	99.96%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Motor	100.00%	99.99%	99.99%	99.97%	99.95%	99.92%	99.88%	99.84%	99.79%	99.72%	99.64%	99.55%	99.45%	99.34%	99.22%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Xfmr power	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Xfmr H	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fuse	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Circuit Brk	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Switch	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Relay	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Solenoid	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Figure ED 5-49. Example Reliability Model Computations for Newburgh Main Chamber Lock Electrical System

life" that was utilized from the component and provides a guide for subsequent replacements. In this analysis, useful life is equal to characteristic life, α.

Obsolescence

Components such as the motor control center (MCC) and transfer switches usually reach the end of their "useful life" when repair parts and other relative hardware cease to be available from the manufacturer. These components will usually require repair/service before they become obsolete, but this analysis does not consider them failed until parts are not readily available. Historic precedent and engineering judgement must be used for the values of these components.

5.6.6 Model Distribution

The modes of failure for electrical equipment are very complex (i.e. they involve a wide variety of distresses such as temperature, vibration, mechanical stresses, etc.) resulting in extreme difficulty or inability to select β values for a Weibull distribution. Since the values were not known, an initial value of 1.0 was used as recommended by ETL 1110-2-549. Using an initial value of 1.0 tends to reduce the Weibull distribution equation to an exponential distribution for the computation of the reliability value. After initial results indicated exceedingly high hazard rates, it was decided that other β values would provide a more sensible answer based upon historical performance. During model calibration, it was agreed by the engineering team to use a value of 2.5 for the motor control center, panel board,

controller, and motors. This combination of β values seemed to give the proper range of values for the overall hazard rate. The exponential reliability equation is:

$$R(t) = e^{-\lambda' t'}$$

where,

λ' = adjusted failure rate, failures/year
t' = adjusted time variable (operation time), years

One other key item to note is that several "small" components such as fuses, solenoids, switches, and circuit breakers were set to be 100% reliable for the entire study period. Because these components could be repaired without closing the chamber, and at a very minor cost, the team decided to "eliminate" these from the failure calculations and assume they were always working properly. Making these "minor failures" part of the overall calculation tended to yield a very high hazard rate that did not seem realistic when determining the long-term reliability of the electrical system. Another reason that these values were selected was the overall reliability process agreed by the team. The team believed the better option for all of the reliability models (miter gates, culvert valves, etc.) was to investigate significant type of limit states, thus, ones that caused extended chamber closures and had high repair costs. All the components that were made 100% reliable for this study would cause neither an extended chamber closure nor costly repair if they failed to perform satisfactorily.

5.6.7 Lock Electrical Sub-Components Analyzed

The overall system analyzed was the provision of power to operate the lock. The overall system was modeled by the process as described by ETL 1110-2-549, but calibrated to give reasonable results. There is no recorded historical data available regarding the lock electrical components or system reliability. Much of the reliability information for the electrical components was readily available in published sources, which was also referenced by ETL 1110-2-549. However, some of the published reliability information was not based on operating conditions or environments similar to the sites conditions associated with locks and dams. Therefore, the team used varying β values and made minor components 100% reliable as part of the calibration process to get results that seemed reasonable based upon historical observations.

The lock electrical service for Newburgh is comprised of two power sources, the electric utility service entrance, (CP, commercial power), and the standby diesel generator, (DG) with wire (WP, wire, power), fuses, (F), and circuit breakers (CB) which feed the motor control center (MC). The power sources are "stand-by redundant" because the system continues to operate successfully if either of the sources operate and as long as power is transferred successfully. The Newburgh electrical distribution subsystem diagram for power to the project is organized as shown in Figure ED 5-50.

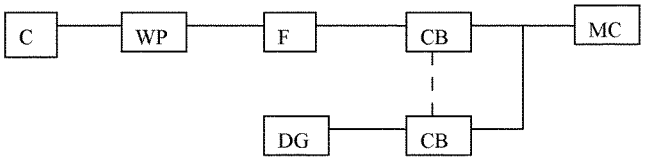
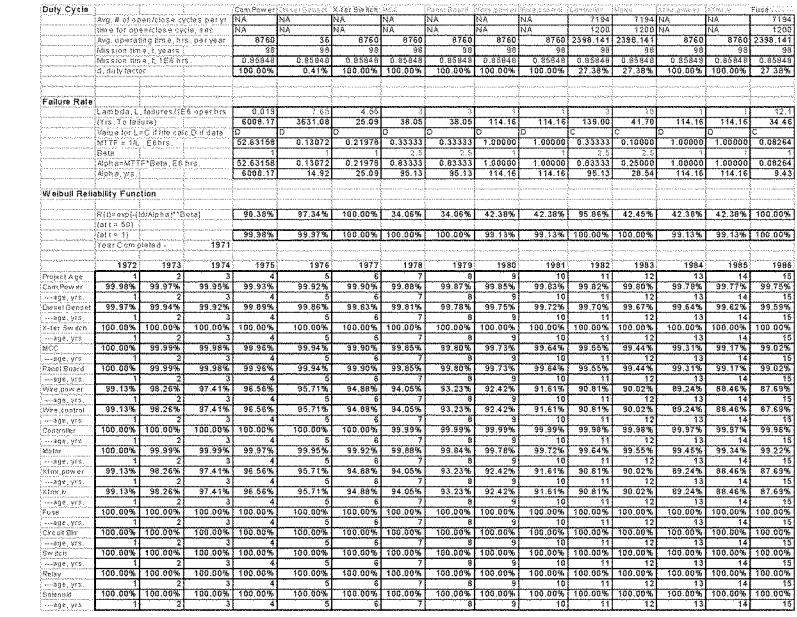


Figure ED 5-50. Newburgh Lock Electrical Service Block Diagram



Duty Cycle																
	Avg. # of open/close cycles per yr															
	time for open/close cycle, sec															
	Avg. operating time, hrs. per year															
	Mission time, t, years															
	Mission time, t, 1E6 hrs															
	d, duty factor															
Failure Rate																
	Lambda, L, failures/1E6 oper hrs															
	(Yrs. To failure)															
	Value for L/C if do calc D of data															
	MTTF = 1/L, E6hrs															
	Beta															
	Alpha=MTTF*Beta, E6 hrs															
	Alpha, yrs															
Weibull Reliability Function																
	R(t)=exp[-(t/Alpha)^Beta]															
	(at t = 50)															
	(at t = 1)															
	Year Completed	1971														
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Project Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Cam Power	99.98%	99.97%	99.95%	99.93%	99.92%	99.90%	99.88%	99.87%	99.85%	99.83%	99.82%	99.80%	99.78%	99.77%	99.75%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Diesel Genset	99.97%	99.94%	99.92%	99.89%	99.86%	99.83%	99.81%	99.78%	99.75%	99.72%	99.70%	99.67%	99.64%	99.62%	99.59%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
X-fer Switch	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
MCC	100.00%	99.99%	99.98%	99.96%	99.94%	99.90%	99.85%	99.80%	99.73%	99.64%	99.55%	99.44%	99.31%	99.17%	99.02%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Panel Board	100.00%	99.99%	99.98%	99.96%	99.94%	99.90%	99.85%	99.80%	99.73%	99.64%	99.55%	99.44%	99.31%	99.17%	99.02%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Wire power	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Wire control	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Controller	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	99.99%	99.99%	99.98%	99.99%	99.98%	99.98%	99.97%	99.97%	99.96%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Motor	100.00%	99.99%	99.99%	99.97%	99.95%	99.92%	99.88%	99.84%	99.78%	99.72%	99.64%	99.55%	99.45%	99.34%	99.22%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Xfmr power	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Xfmr lv	99.13%	98.26%	97.41%	96.56%	95.71%	94.88%	94.05%	93.23%	92.42%	91.61%	90.81%	90.02%	89.24%	88.46%	87.69%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Fuse	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Circuit Brk	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Switch	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Relay	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Solenoid	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	
---age, yrs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

Figure ED 5-49. Example Reliability Model Computations for Newburgh Main Chamber Lock Electrical System

life" that was utilized from the component and provides a guide for subsequent replacements. In this analysis, useful life is equal to characteristic life, α.

Obsolescence

Components such as the motor control center (MCC) and transfer switches usually reach the end of their "useful life" when repair parts and other relative hardware cease to be available from the manufacturer. These components will usually require repair/service before they become obsolete, but this analysis does not consider them failed until parts are not readily available. Historic precedent and engineering judgement must be used for the values of these components.

5.6.8 Model Distribution

The modes of failure for electrical equipment are very complex (i.e. they involve a wide variety of distresses such as temperature, vibration, mechanical stresses, etc.) resulting in extreme difficulty or inability to select β values for a Weibull distribution. Since the values were not known, an initial value of 1.0 was used as recommended by ETL 1110-2-549. Using an initial value of 1.0 tends to reduce the Weibull distribution equation to an exponential distribution for the computation of the reliability value. After initial results indicated exceedingly high hazard rates, it was decided that other β values would provide a more sensible answer based upon historical performance. During model calibration, it was agreed by the engineering team to use a value of 2.5 for the motor control center, panel board,

5.6.9 Electrical System Event Tree

The event tree for the electrical system is set up slightly different than that of the structural components. An extra branch on the event tree was added to differentiate between minor and major types of failures of the significant electrical components. Thus, there are many more failure options evaluated for the electrical system. The failure rates from the manuals reflect mainly wear-and-tear type of failures such that most repairs would be minor in nature. Therefore, the first branch of the event tree is the hazard rate for the electrical system. The second branch delineates between major and minor failures. Like the structural components, the event tree for the electrical system also has a sliding scale used for the major and minor branches related to service age of the system. For lock electrical systems with less than 30 years of service, 25% was used for major branch and 75% of the minor branch. This relationship changes to 35% major/65% minor for lock electrical systems between 31 and 50 years of service, and finally an even 50% split for lock electrical systems in service over 50 years. The event tree used for the lock electrical system is shown in Figure ED 5-53. A cost and closure breakdown for each of the major and minor types of repairs is supplied for the event tree.

Major Failure Branch

There are three branches off of the major failure branch portion of the event tree. These are catastrophic failure with a new, unplanned electrical system, a major overhaul of the electrical system, and finally, replacing one major component. Each of these is detailed below.

Major Failure, Unplanned New Electrical System. This assumes a total failure of the electrical system. The failure is assumed to be non-repairable such that a new, unplanned electrical system is required for the lock. It is estimated that the electrical system would cost $4,00,000 to replace under emergency conditions. The cost of this was provided by electrical engineers in consultation with operations personnel. The lock is assumed to be closed for 365 days under this scenario. This is due to the fact that this would be an unscheduled closure and a replacement system would need to be designed and procured. Because this is the least likely repair method, a small chance was assigned to this level. This will vary according to service life of the electrical system. For the first 30 years of service life, a 2.5% chance of occurrence is derived from taking the 10% assigned to the branch multiplied by the 25% associated with the major failure branch. Future reliability of the electrical system once it is replaced is assumed to be 1.0 for the purposes of this study.

Major Failure, Major Overhaul of Electrical System. This assumes numerous failures to the electrical system such that an upgrade of several major components is required, but not a full replacement of the entire electrical system. Parts that are not replaced are assumed to be in good condition and provide continued adequate service. The estimated cost of this repair scenario is $750,000 and was provided by ORMSS electrical engineers in consultation with operations personnel. Since this also repsents a "reactive" repair, an extended closure of 90 days was estimated to be required to procure replacement parts, install them, and get the chamber serviceable again. The team developing this information estimated that these parts and the parts not replaced would provide about 20 years of adequate service, thus, the "effective" improvement in reliability following the repair was to slide back the hazard rate by 20 years. A 7.5% chance was assigned to this repair level for the first 30 years of service life by taking the 30% for the repair level multiplied by the 25% for the major failure branch. Therefore, it is assumed that this is not a likely repair scenario given a failure of the electrical system.

The resulting reliability equation for this segment of the Newburgh electrical distribution system is:

$R(t)_{JTMyers} = [1-[[1-CP(t)*WP(t)*F(t)*CB(t)]*[1-DG(t)*CB(t)]]][MC(t)]$

Lock Electrical Distribution, Power to Hydraulic Pumps

Three hydraulic pumps in parallel provide hydraulic power for the gates. Each of these circuits is comprised of a controller/contactor (C), a circuit breaker (CB), and the motor (M) and can operate independently of the other two. The diagram of the resulting electrical subsystem is organized as follows in Figure ED 5-51.

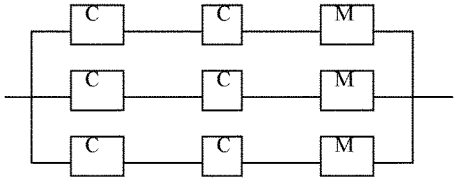


Figure ED 5-51. Block Diagram for Power to the Three Parallel Hydraulic Pumps

Each of the pump motors (M) is fed from a circuit breaker (CB) through a controller/contactor (C). The resulting reliability equation for this segment of the electrical distribution system is:

$R(t)_{Figure3}=[1-[1-[CB(t)*C(t)*M(t)]]\text{^}3]]$

Lock Electrical Distribution, Control Power

Power for the Newburgh controls are stepped down with a control transformer (T), that is fed from a circuit breaker (CB). The control power feeds through the control wiring (WC), two circuit breakers (CB), and a panelboard (PB). This control power feeds the open/closed controller (C) which directs the power through the limit switches (LS) to the respective emptying\filling valve (SV).

The diagram of the resulting electrical subsystem at Newburgh is organized as follows in Figure ED 5-52.

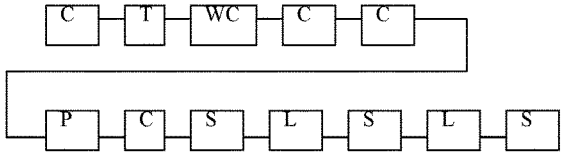


Figure ED 5-52. Newburgh Block Diagram for Power to the Controls

The resulting reliability equation for this segment of the Newburgh electrical distribution system is:

$R(t)_{JTMyers}=[CB(t)^3*T(t)*WC(t)*PB(t)*C(t)*SV(t)^3*LS(t)^2]$

Major Failure, Replace Single Component. This assumes that only a single major component needs to be replaced and all others are in good condition. It is assumed that the part requires a special order and will cost roughly $250,000. Chamber downtime is estimated at 15 days, but would vary according to the part that needs to be replaced. The electrical system is assumed to be in relatively good condition other than the major part that needs to be replaced. It is assumed replacing the the failed component effectively improves the reliability by 15 years. This is considered to be the most likely repair level under the major failure branch of the event tree. An 15% chance was assigned to this repair for the first 30 years of service life by taking the 60% multiplied by the 25% for the major failure branch.

Minor Failure Branch

There are two branches off of the minor failure portion of the event tree. These are a major overhaul of the electrical system and replacing a single component. An unplanned, new electrical system was left out of this branch since than can not be considered a minor failure. Each of these "minor" failures is detailed below.

Minor Failure, Overhaul of Electrical System. This assumes numerous failures to the electrical system such that an upgrade of several electrical components is required, but not a full replacement of the electrical system. Parts that are not replaced are assumed to be in good condition. The difference between this repair and the major overhaul for the major failure branch is the assumption that the diagnosis of the problem and repair time takes less time than under the other major failure branch. Thus, for this repair scenario, replacement parts are readily available and/or already on-hand. Therefore, only 5 days of chamber closure is required for this closure. The cost for this option was estimated at $225,000 by ORMSS electrical engineers and operations personnel. A 22.5% chance was assigned to this repair level for the first 30 years of service life by taking the 30% for the repair level multiplied by the 75% for the minor failure branch. With a overhaul, not all parts are new, however, the major components would be new and thus, the reliability is assumed to be upgraded to what it was 10 years previous to the failure.

Minor Failure, Replace Single Component. This assumes that only a single component needs to be replaced and all others are in good condition. However, it is assumed replacing the component only has a minimal effect of improving the overall reliability of the electrical system (effective 5 years). A chamber closure of 1 day is assumed for this repair, thus, the replacement part essentially must be on-site and ready to install following a failure. As opposed to the major failure branch, it is assumed that the single component is cheaper and a smaller crew would be required to install it for the minor failure branch. A cost of $75,000 is assumed for this repair. This is considered to be the most likely repair level in the entire event tree. A 52.5% chance was assigned to this repair for the first 30 years of service life by taking the 75% multiplied by the 70% for the minor failure branch.

5.6.10 Hazard Rates and Calibration of Model

One of the first revisions required once the initial model was developed was to attempt and calibrate to a combination of historical performance at typical Ohio River lock projects and the engineering team's judgment. Immediately it was evident that several minor components were controlling the hazard rates in the results. These components were items such as fuses, switches, circuit breakers, relays, and solenoids. The team agreed that since these parts were easily replaceable and spares were readily available any chamber down time or repair cost would be insignificant in the overall economic analysis. Therefore, for the purposes of this study, it was assumed that all fuses,

circuit breakers, switches, solenoids, and relays were 100% reliable so they did not affect the overall electrical system hazard rate.

As noted previously, the failure rates for the different components are pulled from data books for the electrical systems as outlined in ETL 1110-2-549. Therefore, the failure rates from the data books lead to an overall electrical system hazard rate that is much smoother and always increasing when compared to the capacity versus demand hazard rates for structural components. The hazard rate for the main chamber electrical system at Newburgh is shown in Figure ED 5-53 for the high (NAAQS), middle (Utility High), and low (Clear Skies). The hazard rates for main and auxiliary chamber are only slightly different even though the operating cycles on the main chamber are considerably higher. This is due to the fact that the majority of the components in the system are operational all the time and not just when lockages occur. The panel board, wires for power and control, transformers, and commercial power are more a function of age because they are continually charged. The ages of the main and auxiliary chamber are essentially the same. Therefore, the difference between the two chambers is primarily due to only two components, the controller and motor. These two components are a function of the number of operating cycles. The other components that are a function of the operating cycles were the minor components that were assumed 100% reliable because they were insignificant in terms of repair cost and chamber down time.

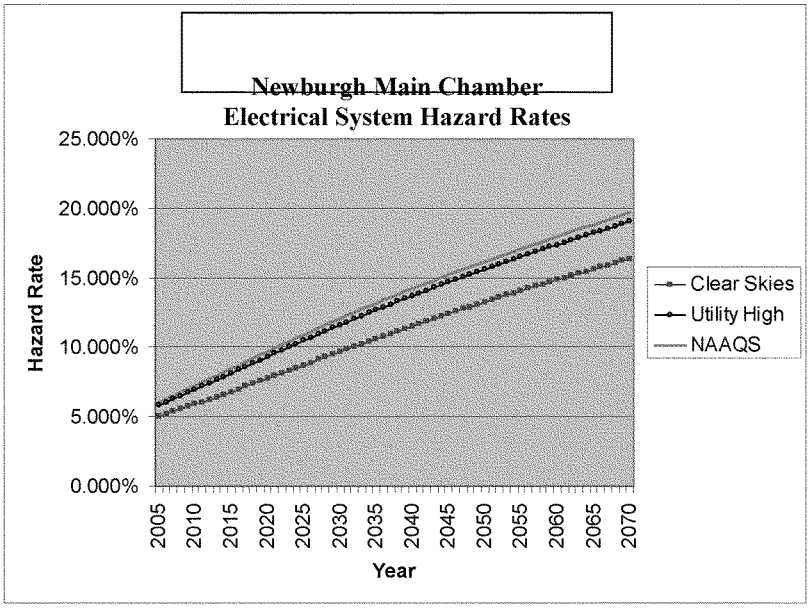


Figure ED 5-53. Newburgh Main Chamber Electrical System Hazard Rate

5.6.11 Economic Results for Main Chamber Electrical Systems

The hazard rates for the electrical systems for all Ohio River locks, along with the event tree shown in Figure ED 5-52, were provided to the economists to determine if a scheduled replacement of

the electrical system for the lock was economically justified for replacement ahead of reaching a level of unsatisfactory performance as outlined in the modeling setup, as well as determine the average annual costs associated with the fix-as-fails scenario. It should be noted that the same event tree was used for the both the main and auxiliary lock chambers since essentially all the electrical components are the same with a few minor differences. However, the auxiliary chamber hazard rates are lower than the main chamber since less traffic locks through the auxiliary. In addition, a closure of the auxiliary is much less critical than a closure to a main chamber. As noted earlier, only a few components within the same chamber tend to cause significant variance in the hazard rates between difference traffic scenarios. Thus, the hazard rate differences between the lowest (Clear Skies) and highest (NAAQS) scenarios for the main chamber electrical system does not vary greatly due to this and the fact that projected cumulative traffic cycles between these scenarios varies only by 26% at Newburgh, which is considerably less that the difference at some of the other Ohio River sites. Higher hazard rates earlier are encountered for the electrical system compared to the structural components, however, the required closure time is considerably less than those provided in the miter gate event tree. As expected, the relatively tight band on the hazard rates for the main chamber electrical system at Newburgh yields projected replacement dates that are close to one another across all traffic scenarios. The optimized replacement dates were determined by ORNIM for the main chamber are provided in the Economics Appendix.

A reliability analysis for the Newburgh auxiliary chamber was also completed for the electrical system and it was determined that the fix-as-fails is the most economical solution. This is not surprising given the fact that the auxiliary chamber is primarily used for recreational vessels and its hazard rates are lower than those on the main chamber. For the summarized results (replacement dates and/or fix-as-fails selection) for all electrical system reliability analyses of all Ohio River lock chambers, refer to the Economics Appendix.

5.7 MECHANICAL SYSTEM RELIABILITY FOR THE LOCK

The mechanical systems for the lock essentially are made up of three major components: miter gate machinery, culvert valve machinery, and the supporting hydraulic system. Because each of these components has different failure conditions and subsequent repairs with differing consequences, each component was independently tracked in the overall mechanical model. Therefore, hazard rates and separate event trees were developed for each of the three components in both chambers. The reliability analyses for the mechanical components at each site were completed as part of the overall analysis. For the purposes of this report, only the mechanical system reliability analysis for Belleville Locks and Dam will be shown for clarity sake.

5.7.1 Assessment of Reliability for Mechanical System

The mechanical reliability assessment is based in principle on procedures defined by ETL 1110-2-549, Engineering and Design, RELIABILITY ANALYSIS OF NAVIGATIONAL LOCK AND DAM MECHANICAL AND ELECTRICAL EQUIPMENT. However, it should be noted that the failure rates and other relevant information listed in the ETL is for mechanical equipment is not necessarily from locks and dams. Therefore, careful consideration was given when using select failure rates and other information from this ETL. Calibration with field conditions was used to the best extent possible. The following paragraphs document the assumptions, current conditions and provide the results of the reliability assessment.

5.7.2 Component Condition Investigations

The Belleville project has two lock chambers. The main chamber for each site is 110 feet wide by 1,200 feet long. The auxiliary chamber at each site is 110 feet wide by 600 feet long. The main chamber has an upper and lower set of miter gates and two filling and two emptying reverse tainter gate style culvert valves. The auxiliary chamber has an upper and lower set of miter gates and one filling and one emptying reverse tainter gate style culvert valve. Each miter gate and culvert valve is operated by a hydraulic cylinder connected to a central pump system. Three main pumps and one small pump operate the hydraulic system for the entire locks. The lock machinery at both projects is the original equipment installed when the project was completed. Periodic inspections and review of the original lock design drawings were conducted to assist in finding the current condition of the mechanical systems.

5.7.3 Selected Limit States for the Mechanical System

The probability of unsatisfactory performance (PUP) was computed from time of installment through the year 2070. It was computed in increments of years between these times to provide a trend of unsatisfactory performance. The limit state was defined as the "meanlife" or Mean Time to Failure (MTTF) of the components analyzed.

5.7.4 Lock Mechanical Systems and Subsystems Analyzed

For this analysis, each of the four mechanical gate systems and each of the valve systems were considered separate models. The diagram is shown in Figure ED 5-54. The valve machinery systems diagram for Belleville is shown in Figures ED 5-55. Finally, the hydraulic system line diagram for the Belleville project is shown in Figures ED 5-56.

5.7.5 Reliability Block Diagram Formulation

This analysis and the formulation of the system reliability block diagrams (RBD) are in accordance with ETL 1110-2-549. The machinery functions to operate the miter gates and reverse tainter culvert valves. The major components required for mission success are defined and organized into an RBD. For the miter gate subsystems for the main chamber, if one component does not function, then the entire system for that chamber will not function. On the auxiliary chamber, if one of the culvert valves or miter gate systems does not operate then the entire system will not function. There are no parallel or redundant items, therefore, the mission and basic block diagrams are arranged as series system models. In this analysis, the structural supports and anchorages are not included in the model. They are unique to the system and there is no published failure rate data available.

5.7.6 Subsystem Reliability Calculation

a. Duty Cycle. The miter gate equipment was considered to have a negligible failure rate during periods ~~of non-operat~~ion (ignoring barge impact). The failure rate can be modified by a duty cycle factor. The duty cycle factor is the ratio of actual operating time to total mission time, t. The lock equipment operates a certain number of open/close cycles per year depending upon the traffic projection scenario. The same process is used to determine the duty cycle for the other lock chambers by using the appropriate values for other lock chambers and corresponding traffic scenarios.

b. Environmental Conditions. The environmental conditions were defined for the ambient service of the lock equipment as an outdoor marine environment. The environmental K factors were selected from Table C-l of ETL 1110-2-549. For this analysis, a K_1 factor of 2.0 is used and K_2 and K_3 are 1.0.

c. Lock Equipment Reliability. The Weibull distribution was used to perform the reliability analysis for each component in the block diagram. The shape parameter values for b were selected from the values given in Table C-6 of the ETL, by choosing a dominant failure mode for each component. The characteristic life parameter *a* was determined from the failure rate data using the methods presented in the ETL. The failure rates for the lock mechanical components were selected from Table C-7 of the ETL. These failure rates were multiplied by the K factor to obtain a final adjusted failure rate. The parameter *alpha* was determined as follows:

$$\alpha = \frac{\gamma}{\lambda}$$

Where,

γ = (α/MTTF ratio from Table C-2 of ETL 1110-2-549)
λ = Adjusted failure rate = SK

The Weibull reliability function for the components becomes:

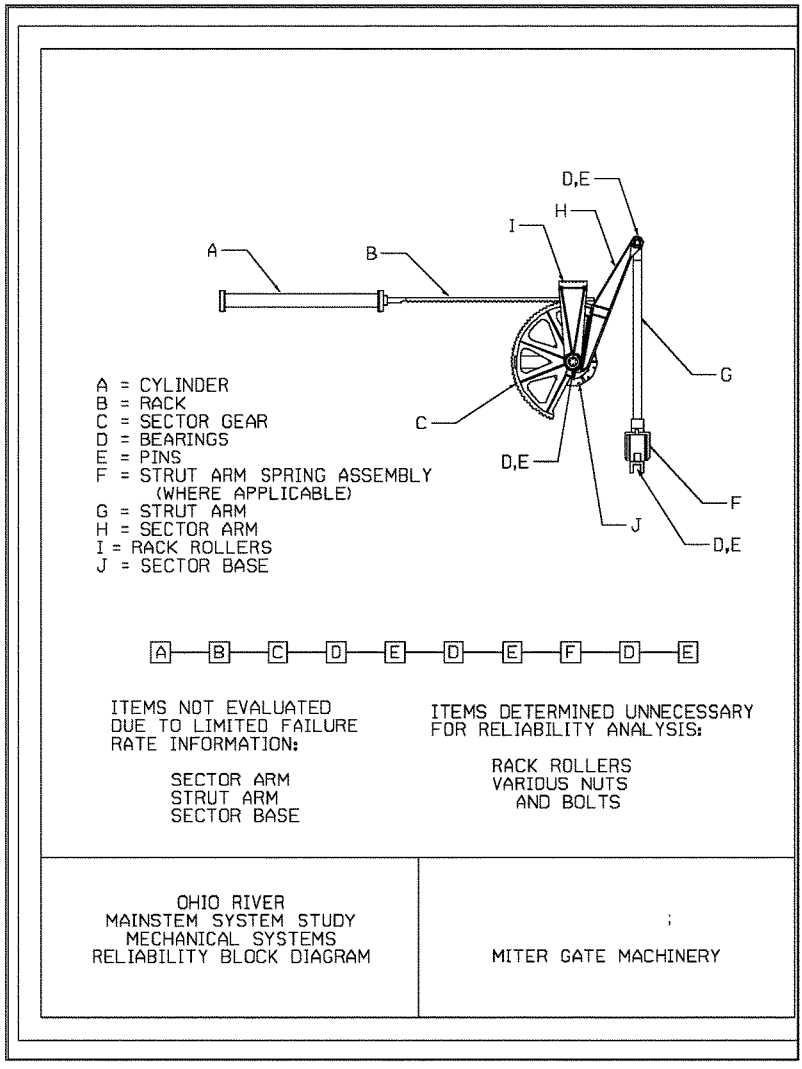
$R(t) = \exp [-(td/\alpha)^{\beta}]$ where t is in years

MITER GATE MACHINERY RELIABILITY

Where the shape parameter (b) is equal to 1.0, the Weibull distribution reduces to the Exponential distribution. The miter gate mechanical subsystem was considered to begin at the first gearset. The subsystem reliability at both projects for the miter gate machinery model in Figure ED 5-62 at time *t* is determined from the individual reliability of each component as follows:

$$R_{MGMachinery}(t) = R_A(t) * R_B(t) * R_C(t) * R_D(t)^3 * R_E(t)^3 * R_F(t)$$

Where,
$R_A(t)$ = Reliability of the cylinder
$R_B(t)$ = Reliability of the rack
$R_C(t)$ = Reliability of the sector gear
$R_D(t)$ = Reliability of the bearings
$R_E(t)$ = Reliability of the pins
$R_F(t)$ = Reliability of the strut arm spring assembly



ED 5-54. Belleville Miter Gate Machinery System

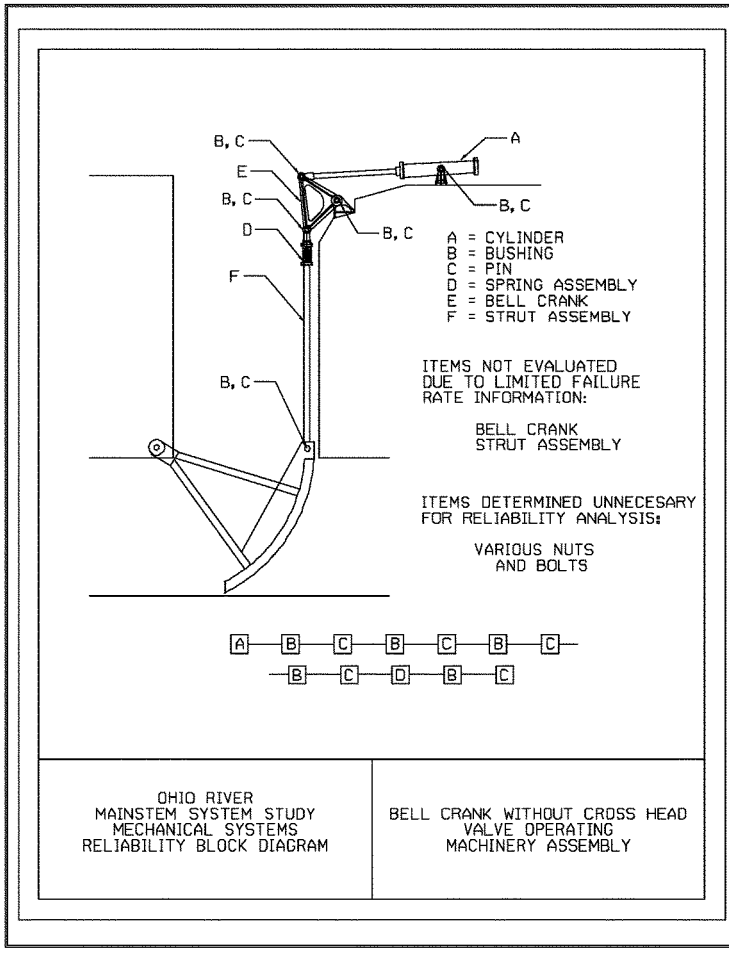


Figure ED 5-55. Belleville Culvert Valve Machinery System

CULVERT VALVE MACHINERY RELIABILITY

The culvert valve mechanical subsystem was considered to begin at the first coupling. The subsystem reliability for the culvert valve machinery model at Belleville (See Figure ED 5-55) is calculated as:

$R_{BellevilleCVMachinery}(t) = R_A(t) * R_B(t)^5 * R_C(t)^5 * R_D(t)$

Where,
$R_A(t)$ = Reliability of the cylinder
$R_B(t)$ = Reliability of the bushing
$R_C(t)$ = Reliability of the pin
$R_D(t)$ = Reliability of the spring assembly

HYDRAULIC SYSTEM RELIABILITY

$R_{HYDRAULIC}(t) = R_{PUMP}(t) * R_{PIPE}(t) * R_{CVHYDR}(t) * R_{MGHYDR}(t)$

Hydraulic Pump System Reliability

$R_{PUMP}(t) = R_C(t) * R_J(t) * [1 - (1 - (R_C(t)^2 * R_F(t) * (1 - (1 - R_B(t))(1 - R_J(t)))))]*[1 - (1 - R_C(t))^2]$

Where,
$R_C(t)$ = Reliability of shutoff valve
$R_J(t)$ = Reliability of filters/strainer
$R_F(t)$ = Reliability of pump
$R_B(t)$ = Reliability of check valve

Culvert Valve Machinery Hydraulic System Reliability

$R_{CVHYDR}(t) = [1 - (1 - R_C^3)(1- R_C*R_G)] * R_C * [1 - (1 - R_{L1})(1 - R_{L2})(1 - R_{L3})]$

Where,
$R_C(t)$ = Reliability of shutoff valve
$R_G(t)$ = Reliability of manual control valve
$R_J(t)$ = Reliability of filters/strainer
$R_H(t)$ = Reliability of solenoid control valve
$R_I(t)$ = Reliability of flow control valve
$R_B(t)$ = Reliability of check valve
$R_K(t)$ = Reliability of the cylinder
$R_{L1} = R_C(t)^2 * R_J(t)$
$R_{L2} = R_H(t)^2 * R_C(t) * [1 - (1 - R_I(t))(1 - R_B(t))]$
$R_{L3} = R_B(t) * R_H(t) * R_D(t)^2 * R_I(t)^2 * R_K(t) * R_C(t)^4$

Miter Gate Hydraulic System Reliability

$R_{MGHYDR}(t) = R_I * R_C * [1 - (1 - R_C^2*R_G)^2] * [1 - (1 - R_K)(1 - R_B^2)(1 - R_D^2)] * [1 - (1 - R_I)^2]$

Where,
$R_C(t)$ = Reliability of shutoff valve
$R_G(t)$ = Reliability of manual control valve
$R_I(t)$ = Reliability of flow control valve
$R_B(t)$ = Reliability of check valve
$R_K(t)$ = Reliability of the cylinder

$R_D(t)$ = Reliability of relief valve

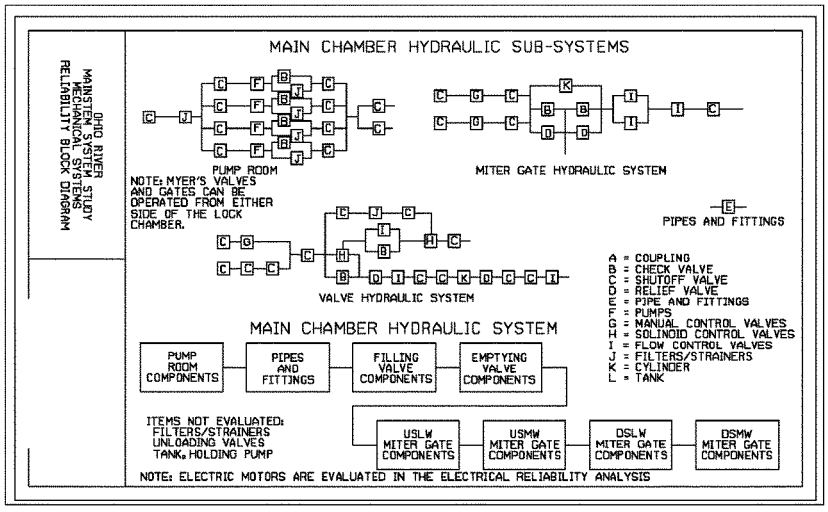


Figure ED 5-56. Belleville Hydraulic System Line Diagram and RBD

5.7.7 Hazard Calculation for the Mechanical System

The Weibull hazard function was used to determine the hazard rate of each component. The Weibull hazard function is:

$$h(t) = \frac{\beta\,[td]^{\beta-1}}{(\alpha)(\alpha)}$$

The subsystem hazard rates for the miter gate and culvert valve models were calculated from the hazard rates of the individual components using the following relationship:

$$h_{subsys}(t) = \sum h_i(t)$$

Where,

$h_i(t)$ = Hazard rate for the individual components
i = 1,n

5.7.8 Mechanical System Event Trees

The event trees for the mechanical systems (miter gate machinery, culvert valve machinery, and hydraulic systems) are set up similar to the electrical system. An extra branch on the event tree was added to differentiate between minor and major types of failures for each of the mechanical components. Thus, there are many more failure options evaluated for the mechanical systems when compared to the structural components. The failure rates from the manuals reflect mainly wear-and-tear type of failures such that most repairs would be minor in nature. Therefore, the first branch of the event tree is the hazard rate for the component (miter gate machinery, culvert valve machinery, or hydraulic system). The second branch delineates between major and minor failures. Like the structural components, the event tree for the miter gate machinery system also has a sliding scale used for the major and minor branches related to service age of the system. These sliding values vary according to service life of the component. The event tree used for the lock miter gate machinery system is shown in Figure ED 5-57. The event tree used for the culvert valve machinery is shown in Figure ED 5-58. Note that ½ speed operation, and not closure time, is the primary chamber performance measure for this component besides repair costs. Finally, the event tree for the hydraulic system is shown in Figure ED 5-59. As was the case with the electrical system event tree, approximate costs and closure times for each branch was determined by ORMSS mechanical engineers in consultation with operations personnel familiar with repairs to these particular components.

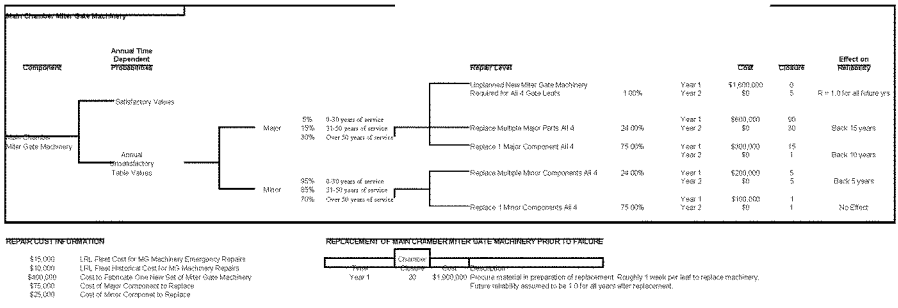


Figure ED 5-57. Miter Gate Machinery Event Tree

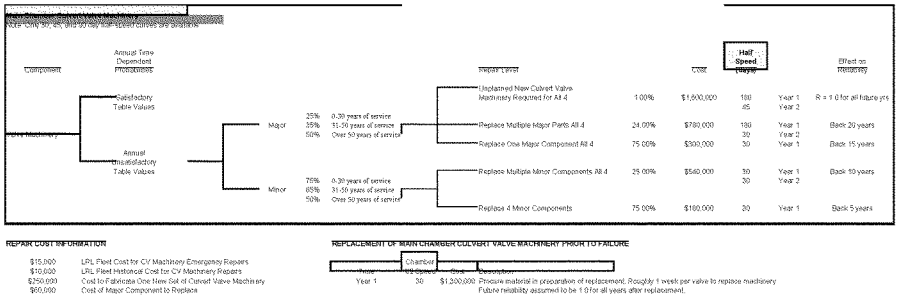


Figure ED 5-58. Main Chamber Culvert Valve Machinery Event Tree

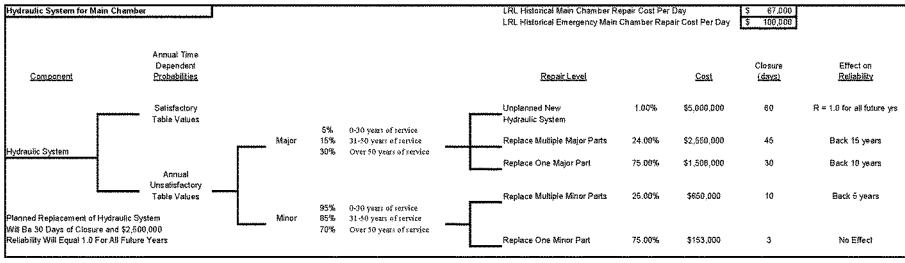


Figure ED 5-59. Lock Hydraulic System Event Tree

5.7.9 Mechanical System Hazard Reliability Model Results

As noted previously, the failure rates for the different components are pulled from data books for the mechanical systems as outlined in ETL 1110-2-549. Therefore, the failure rates from the data books lead to an overall hazard rate that is much smoother and always increasing when compared to the capacity versus demand hazard rates for structural components. The hazard rate for the main chamber miter gate machinery system at Belleville is shown in Figure ED 5-60 for the high (Modified Clear Skies), middle (Utility High), and low (Clear Skies). As shown in Figure ED 5-60, the hazard rates for the miter gate machinery at Belleville do not vary greatly between the low and high scenarios since many features of the miter gate machinery system reliability analysis is age based. However, operating cycles are a contributing factor that makes up part of the difference. The hazard rates for main and auxiliary chamber are only slightly different even though the operating cycles on the main chamber are considerably higher. Similar notes to those described for miter gate machinery hazard rates are applicable to the hazard rates for culvert valve machinery and hydraulic systems. The variation in hazard rates between these components is based upon the failure rates used in the analysis for each of these components from the guidance. The hazard rates for the low, high, and middle traffic projections are shown in Figures ED 5-61 and ED 5-62 for the culvert valve machinery and hydraulic system, respectively.

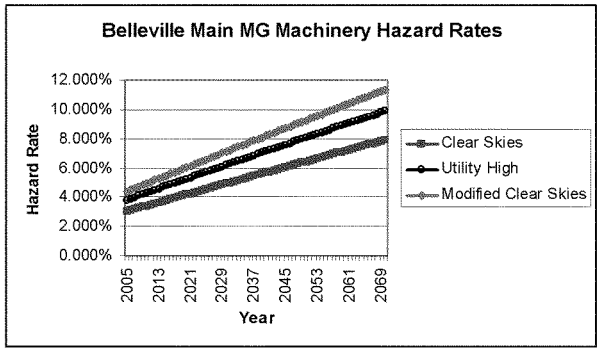


Figure ED 5-60. Belleville Main Chamber Miter Gate Machinery Hazard Rates

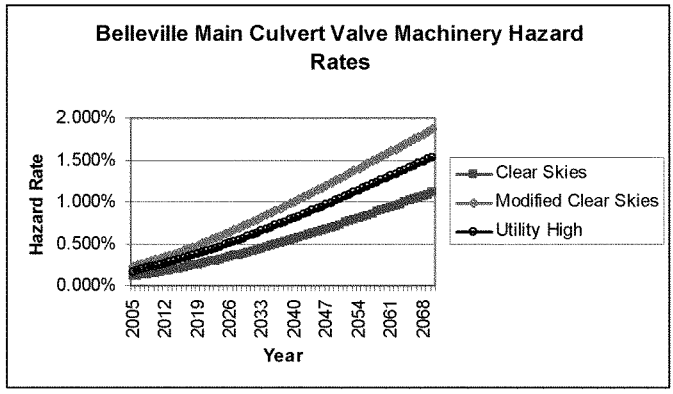


Figure ED 5-61. Belleville Main Chamber Culvert Valve Machinery Hazard Rates

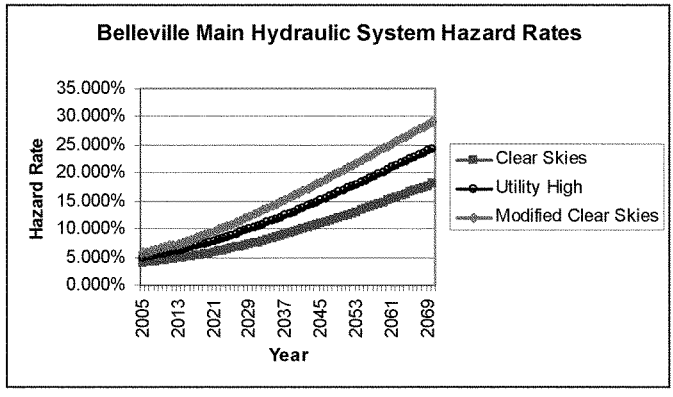


Figure ED 5-62. Belleville Main Chamber Hydraulic System Hazard Rates

5.7.10 Economic Results for Mechanical Systems

The hazard rates for the various mechanical components systems for all Ohio River locks, along with the event trees shown in Figures ED 5-57 through ED 5-59, were provided to the economists to determine if a scheduled replacement of any of the mechanical operation machinery was economically justified for replacement ahead of reaching a level of unsatisfactory performance as outlined in the

modeling setup, as well as determine the average annual costs associated with the fix-as-fails scenario. The same event tree for the miter gate machinery was used for the main and auxiliary chambers. Different event trees for the hydraulic system and culvert valve machinery were used between the main and auxiliary chamber, however, these differences made little difference in the economic results. The differences are mainly driven by the fact that auxiliary chambers are not used for most commercial lockages in addition to the having lower hazard rates compared to the main chamber. As noted earlier, the hazard rates between the low (Clear Skies) and high (Modified Clear Skies) traffic scenarios at Belleville did not vary greatly even though traffic levels are considerably different. This is a function of the failure rate type of analysis applied with the ETL. Future work in this area will be directed towards a capacity versus demand type of analysis like what is done for structural components. If these models can be developed through research and development efforts, they would add great benefit to the Corps risk-based applications.

Using the event trees and hazard rates of the mechanical components at Belleville, the replacement dates for each main chamber component are shown in the Economics Appendix. Graphical representation of the Belleville miter gate machinery, culvert valve machinery, and hydraulic system ORNIM output is shown in Figures ED 5-63, 5-64, and 5-65, respectively, for the Utility High traffic scenario.

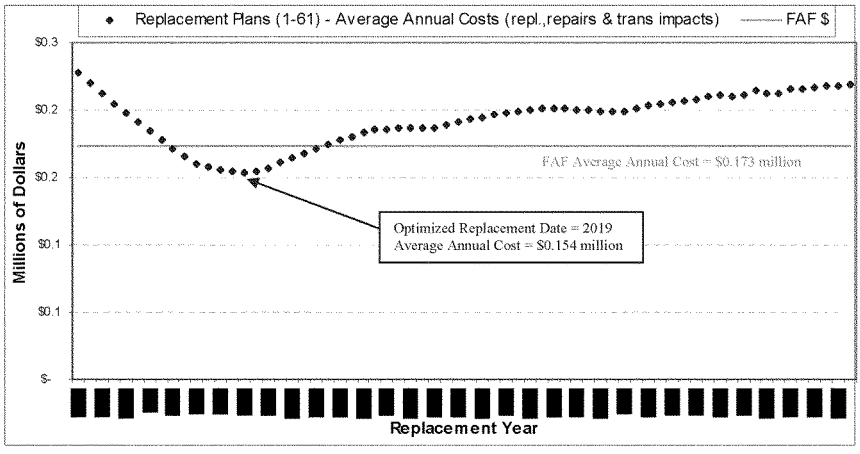


Figure ED 5-63. Economic Results for Belleville Main Chamber Miter Gate Machinery

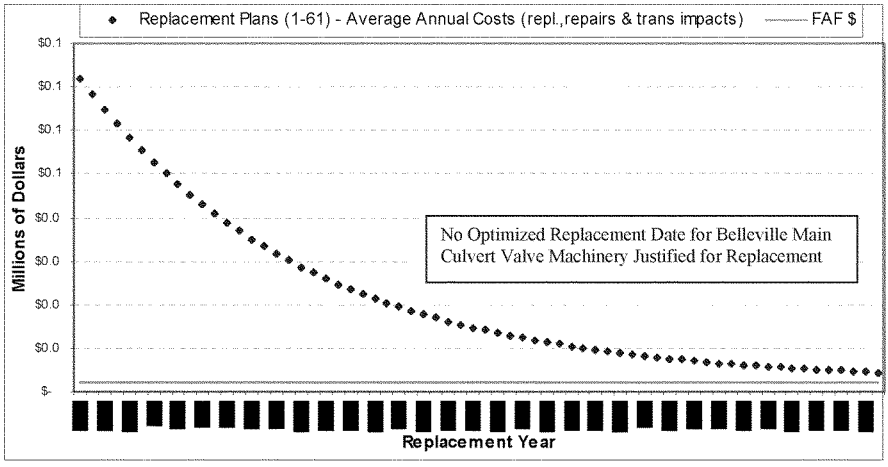


Figure ED 5-64. Economic Results for Belleville Culvert Valve Machinery

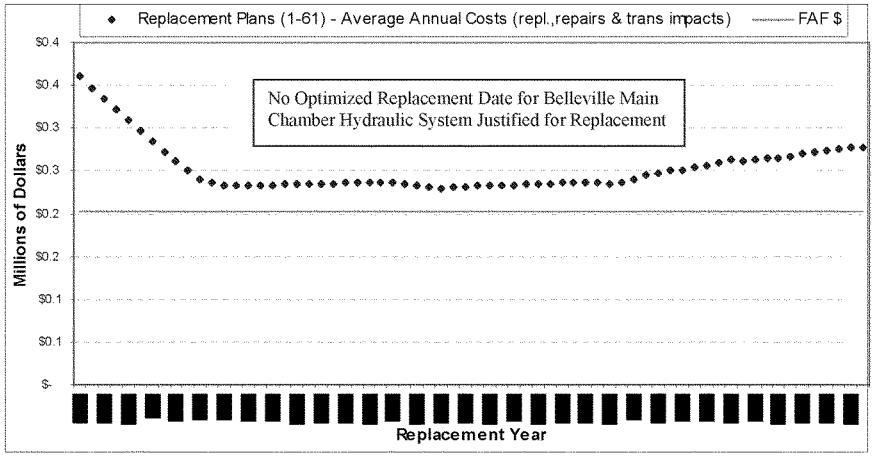


Figure ED 5-65. Economic Results for Belleville Hydraulic System

5.8 GRAVITY MONOLITH RELIABILITY

There are two basic types of concrete gravity monoliths on the Ohio River system, unanchored concrete gravity monoliths and anchored concrete monoliths. The unanchored concrete monoliths are not considered to be time dependent from a reliability standpoint since the ORMSS Engineering Team was not evaluating "return period" types of loads such as earthquakes and floods as part of this evaluation. The anchored concrete monoliths are considered to be time dependent (reliability changes with time) because the anchors are subjected to fatigue and corrosion. There are only three sites on the Ohio River that have anchored concrete monoliths. These are Emsworth, Dashields, and Montgomery (EDM) Locks and Dams in the Pittsburgh District. All other remaining sites have unanchored concrete gravity monoliths for lock walls. As stated previously, their reliability is not assumed to change with time because the structure does not significantly degrade with time. In addition, the reliability analysis did not consider extreme or unusual loads as part of the analysis, as directed by HQUSACE guidance.

Within the unanchored concrete gravity monolith category, there are various types of monoliths that have been analyzed for reliability. These include "typical" land wall, middle wall, and river wall monoliths within the lock chamber. Stability for approach walls was also analyzed for ORMSS. Additionally, the lower, middle wall auxiliary chamber miter gate monolith was analyzed. The engineering team chose this miter gate monolith at each site since it generally experiences the highest uplift, particularly in the maintenance case. Since the uplift has proven to be the most critical load on concrete gravity structures, the team chose to look at this particular monolith.

All of the unanchored monolith sections analyzed are concrete gravity structures founded on rock. Olmsted was not considered because of it was recently constructed and designed with current criteria for uplift, seismic, and safety factors. The same is true for the new lock chamber at McAlpine, which is currently under construction. All of the monoliths analyzed are concrete structures founded on rock and are not stabilized with active or passive rock anchors with the exception of EDM. There are three walls made of individual concrete, gravity monoliths that form the lock chamber. The land wall and one side of the middle wall form the auxiliary chamber. The river wall and other side of the middle wall form the main chamber. Since the time or funding was not sufficient to investigate every possible monolith cross-section for reliability analyses, a typical monolith was selected to be representative for each wall at each project.

5.8.1 Load Cases for Lock Wall Reliability

Because the structures are massive concrete structures without anchors, they are not subject to fatigue and corrosion associated with steel structures. As a result, no significant deterioration over the operational life of the structure is considered to threaten the overall stability of the structure and the reliability is assumed to be independent of time. The exception is at EDM, where significant deterioration of the internal mass concrete is a major reliability concern. The EDM reliability analysis for lock wall stability had to be meshed with the expert elicitation in order to be used in ORNIM. For all other sites besides EDM, the reliability is assumed to be constant over the study period. This is consistent with HQUSACE reliability guidance for unanchored concrete gravity monolith structures. Since the reliability of the structure is based on limit states and not design values, unsatisfactory performance modes considered for the gravity monoliths are overturning, sliding, and bearing of the rock foundation **without any safety factors applied to the analysis**. The limit states established for the unsatisfactory performance modes are as follows: overturning – a negative effective base in compression, sliding – the driving horizontal forces exceed the resisting horizontal forces, and bearing – the resultant monolith toe bearing pressure exceeds the maximum peak bearing strength of the foundation rock or subjacent rock.

In general, calculations were based on current Corps of Engineers lock design criteria. Two loading conditions are considered for the unanchored lock wall monoliths: the normal operating condition and the maintenance condition. The normal operating condition represents the usual daily

cyclic loads experienced by the lock monoliths. Dewatering the chamber is the maintenance condition. As has been the case for all other components, a single site has been selected for the typical analysis of the component. The Markland project is being detailed for lock wall stability.

Table ED 5-5 depicts the loading conditions for both situations for all three types of monoliths at Markland. Normal upper pool at Markland is elevation 455.0. This generally does not vary significantly and therefore is assumed to be constant in the model. Normal lower pool elevation is 420.0; however, the lower pool fluctuates and is a random variable in the reliability analysis. The major external loadings experienced by a land wall are lateral earth pressure, hydrostatic pressure due to the saturation level of the backfill, uplift, hawser pull, and the fluctuating pool elevation in the lock chamber. The middle and river walls are subjected primarily to uplift, hawser pull, and fluctuating pool elevations in the chambers or river. The miter gate monolith is also subjected to hydrostatic effects, but also the miter gate loads. Barge impact is excluded from the analysis since the lock chamber monoliths are not part of the navigational approach system. Barge impact loads were included in the approach wall stability analysis.

Monolith	Load Case	
	Normal Operating Condition	Maintenance Condition
Land	Backfill saturated to EL. 455.0 and fluctuating lower pool in main chamber.	Backfill saturated to EL. 455.0 and the main chamber dewatered, EL. 398.0.
Middle	Main chamber at upper pool, EL. 455.0 and auxiliary chamber at fluctuating lower pool.	Main chamber at upper pool, EL. 455.0 and auxiliary chamber dewatered, EL. 398.0.
River	Auxiliary chamber at upper pool, EL. 455.0 and the river at fluctuating lower pool.	River at fluctuating lower pool (<EL 431.08) and auxiliary chamber dewatered, EL 398.0.

Table ED 5-5. Load Cases for Lock Wall Monoliths (Markland Example)

For the analysis of all gravity structures, an external force resisting overturning was added to the model to account for rock embedment where appropriate. If the embedment was minimal, this external force was neglected in the analysis. The model calculates this force as the passive crossbed shear resistance of the rock wedge on the down stream face of the monolith. For the miter gate monoliths, the analysis included no resistance from the adjacent miter gate sill or adjacent monoliths.

5.8.2 Loading Assumptions

The gravity loads considered in the analysis are due to the weights of the water and soil above the monolith, water within the culvert, and the concrete monolith. For an example of model input, the soil/rock random variables and constant values for the Markland project are provided in the Tables ED 5-6 and ED 5-7, respectively. For the case where the moist soil unit weight exceeds the saturated soil unit weight, the moist soil unit weight is made equal to the saturated soil unit weight in the stability analysis. Lateral earth pressure of the backfill is computed using the full at-rest pressure coefficient (K_o) that is calculated from Jacky's Equation, since the lock monoliths are founded on rock[1,2]. For Markland, the saturation level in the backfill is assumed to be constant and equal to the normal upper pool elevation EL 455.0. Uplift is assumed to be acting on the entire base of the monolith. The uplift pressure values are based on the varying lower pool elevation, constant upper pool elevation, and/or the saturation level in the backfill. The distribution of the uplift pressure was calculated using a derived closed-form solution for uplift that is a function of the overturning and resisting moments, uplift pressures at the toe and heel of the structure, and the resultant vertical load. It is assumed that a uniform uplift pressure equivalent to the maximum hydrostatic pressure at the heel of the base acts on the portion of the base not in compression. A hawser pull is applied to a structure under the normal operating condition for 20

percent of the Monte Carlo trials [typically 10,000 trials] [3]. The hawser pull-force value normal to the face of a monolith is established from the guidance in ETL 1110-2-321 and the point of application is assumed to be 5 feet above the pool elevation[4,5]. Vertical shear (downdrag), acting along the wall-soil interface due to differential settlement of the backfill, is available in the model but was not utilized in the stability analyses since the lock monoliths are completely stable for both normal operating and maintenance conditions.[2,5]

For the miter gate monolith analysis, full hydrostatic head was applied to the upstream and downstream faces and uplift on the base of the structure varies linearly from 100% of headwater to 100% of tailwater with no effect from foundation drains. In the case of the base not being entirely in compression, it was assumed a tension crack is formed and 100% of headwater pressure was applied along the length of the crack then the uplift varies linearly to tailwater from that point. For the normal condition, the hydrostatic and uplift pressures upstream of the centerline of the pintle were based on the upper pool level in the auxiliary chamber, and those downstream were based on lower pool level. All sites with unanchored concrete gravity monoliths have miter gates that are horizontally framed. Therefore, the miter gates transfer the load produced by the differential head directly to the monolith in the normal condition. During the maintenance condition, the weight of the hanging gate is transferred to the monolith as a force couple at the top anchorage and the pintle.

The tables and description of the conditions at Markland are only shown to give the reader a flavor of the model and how it works. Each project had the analysis completed and the same load cases as shown in this narrative. Additionally, the random variables and constants are site-specific values but are input into the model the same as shown for Markland.

5.8.3 Random Variables and Constants in the Analysis

The geotechnical shear strength parameters for all sites are based on information obtained from the as-built drawings, design memoranda, foundation reports, periodic inspection reports, and reference material. Each district's geotechnical engineers provided the necessary data to complete the analysis. Cross-sections, boring logs, N-values, and laboratory test results are used to determine the range in strength values. Very limited test results are available for the majority of the sites. As a result, typical strength values are obtained from reference material and original design values. The probabilistic values used in the reliability analyses include the type of probability distribution function, mean, standard deviation, range, coefficient of variance, and correlation coefficient, and are provided in the following table. Unit weights, shear strength parameters, and ultimate bearing capacity values are provided for the soil and rock foundation. Cross-bed shear strengths are also provided for the monoliths embedded in rock.

5.8.4 Lock Wall Reliability Model Computations

The Microsoft Excel™ spreadsheet and the @Risk™ add-on application is comprised of six sheets (*Input Parameters, Monolith Geometry, Soil Geometry, Water Elevation, Stability Analysis*, and *Stability Results*) and two visual basic modules (*Update* and *VBProgram*). @Risk™ is an add-on software application for Microsoft Excel™ that provides Monte Carlo simulation for reliability analysis. The material properties and input data are represented by probability distribution functions instead of discrete values. For each Monte Carlo trial, material properties and input data are randomly selected according to their respective probability distributions for the stability analysis. The structure is analyzed for its stability in overturning, sliding, and bearing. Any unsatisfactory performance is tabulated for each trial. A sufficient number of trials, 10,000 for this model, are required to achieve convergence and

a particular level of confidence in the simulation results. The general model spread sheets are set up similar to the model for the miter gate sills.

Variable	Mean	Standard Deviation	Maximum	Minimum	Distribution	Units	Description
Soil:							
Mst Unit Wt	0.115	0.003	0.124	0.106	Normal	kcf	Driving soil, unit weight, moist
Sat. Unit Wt	0.125	0.004	0.137	0.113	Normal	kcf	Driving soil, unit weight, saturated
Phi, internal	33	2	38	30	Normal	deg	Driving soil, internal friction angle
Rock:							
Phi, sliding	38	4	45	35	Normal	deg	Rock, sliding friction angle
C, sliding	20	20	25	0	Normal	psi	Rock, sliding shear strength
Phi crossbed	47	4.5	57	37	Normal	deg	Rock, cross-bed friction angle
c, crossbed	75	25	100	50	Normal	psi	Rock, cross-bed shear strength
Sat Unit Wt	0.1672	0.002	0.1697	0.1660	Normal	kcf	Rock, saturated unit weight
BrgCapacity	2083.3	208.3	2430.6	1736.1	Normal	psi	Rock, ultimate bearing capacity
Lower Pool					CDF [1/,2/]	NA	Lower Pool elevation
Hawser Pull	57.5	11.5	80.5	34.5	Normal	kip	Hawser pull force, normal to face

[1/] Cumulative Density Function established for Lower Pool is used.

[2/] For river wall R-48, the maintenance condition, the maximum main chamber is flooded when the lower pool elevation exceeds EL 431.08.

Not applicable.

Table ED 5-6. Geotechnical Random Variable Parameters (Markland Example)

Constant	Value	Units	Description
Conc Unit Wt	0.1475	Kcf	Concrete, unit weight
Water Unit Wt	0.0625	Kcf	Water, unit weight
Saturation Level	455.0	Ft	Water saturation level in backfill
Upper Pool	[1/] 455.0	Ft	Upper Pool elevation

[1/] When L.P. EL > U.P. EL – 1 ft, U.P. EL = L.P.EL + 1 ft.

Table ED 5-7. Geotechnical Constants for (Markland Example)

For the lock wall monolith reliability model, the probability distribution functions, parameters, and constants are provided in the *Input Parameters* sheet. The geometry, voids, and centroid computation of the monolith are provided in the *Monolith Geometry* sheet. Soil geometry is provided for one or two types of backfill and the sheet calculates the moist and saturated soil layers, weights, and centroids using the visual basic *Update* functions. The lower pool cumulative density function and upper pool discrete value are provided in the *Water Elevation* sheet. Soil and rock elevations for computation of driving and resisting forces are provided in the *Stability Analysis* sheet. The stability calculations and results for overturning, sliding, and bearing are provided in the *Stability Results* sheet. A visual basic module is used to track unsatisfactory performances during the Monte Carlo trials. The respective unsatisfactory performances for each limit state and cumulative unsatisfactory performances are also tabulated on this sheet.

The stability analyses follow the guidance provided in Chapter 4 of EM 1110-2-2502. For the overturning stability analysis, the vertical and horizontal forces and the resultant moments are summed. The resultant moments are categorized as resisting or overturning moments. The effective base in compression and the uplift is solved for simultaneously using a closed-form solution. The closed-form

solution is a function of the overturning and resisting moments, uplift pressures at the toe and heel of the structure, and the resultant vertical load. A negative effective base in compression indicates that the structure performs unsatisfactorily in overturning. Once the effective base and uplift are established, the sliding stability analysis is conducted. The passive resistance of the rock and structural wedge is computed and the resisting forces are summed with the resultant net negative driving forces. If the sum of the resisting and driving forces is negative, the structure performs unsatisfactorily in sliding. The maximum bearing pressure is then calculated and compared to the ultimate bearing capacity for the rock foundation. If the bearing pressure exceeds ultimate bearing strength, the structure performs unsatisfactorily in bearing. Each mode of unsatisfactory performance is tabulated for each trial. However, any trial that results in a calculated unsatisfactory performance in any one or combination of the three performance modes will be counted for reliability purposes as one unsatisfactory performance for the structure.

5.8.5 Results and Conclusions

No unsatisfactory performances were calculated in 10,000 iterations for both the normal and maintenance load cases for any of the non-EDM sites. There were no unsatisfactory performance occurrences because of the original safety criteria used in design of the structures. Additionally, each site is founded on sound rock that resists all three possible failure modes.

These results are reasonable and expected since no significant movement of the walls has been noted at any of the sites since construction. Since there were no unsatisfactory performances, the economists did not need to run their analysis for the lock wall monoliths at the sites that have been completed. Thus, the event tree for lock walls is not included with this appendix.

5.8.6 References

1. Headquarters, Department of the Army. (1989). "Retaining and Flood Walls," Engineering and Design, EM 1110-2-2502, Washington, DC.
2. Headquarters, Department of the Army. (1997). "Stability Analysis of Concrete Structures," Engineering and Design, EC 1110-2-291, Washington, DC.
3. ORMSS Meetings – Discussions with Operations and Design Sections.
4. Headquarters, Department of the Army. (1993). "Reliability Assessment of Navigational Structures, Stability of Existing Gravity Structures," Engineering and Design, ETL 1110-2-321, Washington, DC.
5. Ebeling, R. M., M. E. Pace, WES, and E. E. Morrison, Jr., N.A.S. Fallon. (1997). "Evaluating the Stability of Existing Massive Concrete Gravity Structures Founded on Rock," Technical Report REMR-CS-54, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

5.9 LOCK CHAMBER MAJOR REHABILITATION EVALUATIONS

One of the key analyses being evaluated within ORMSS is the need and timing of major rehabilitations for individual lock chambers. This was analyzed for each lock where the number of components justified for replacement would exceed the current monetary threshold for major rehabilitations and last over at least two construction seasons, as required by current USACE guidance. The current threshold for major rehabilitation is approximately $10.8 million spread over multiple years. For the purposes of this study, the rehab "package" was considered to be all components that were individually justified for component replacement within the study period. The cost of individual

component replacements, which requires separate closures and repair costs, was compared against a major rehab option where the components are "bundled" into a single project with multiple closures over 2 to 3 construction seasons. In most cases, the rehab option was selected by ORNIM as the least cost alternative since more closures are eliminated and future reliability is reset to a value of 1.0 for each component replaced, thus, eliminating future failures within the analysis. The lock chamber selected for illustrating the major rehabilitation analysis for ORMSS is the Cannelton main lock chamber. The analysis is shown for the Clear Skies forecast.

The following individual components are economically justified for replacement ahead of failure for the Cannelton main lock chamber: miter gates, miter gate machinery, hydraulic system, culvert valves, and electrical system. The cost and closure time required for individual component replacements is evaluated versus the closure time and cost associated with a major rehabilitation of the lock chamber. As noted earlier, the major rehabilitation was only evaluated if it met the current requirements of the major rehab program, primarily cost and construction time. A comparison of the projected individual component replacements of the Cannelton main lock chamber versus a projected major rehab cost and closure requirements is shown in Table ED 5-8.

Component	Year 1 Repair Cost / Closure	Year 2 Repair Cost / Closure	Year 3 Repair Cost / Closure
Miter Gates	$6.5 M / 0 days closed	$8.8 M / 30 days closed	$3.8 M / 30 days closed
Culvert Valves	$0.9 M / 0 days ½ speed	$2.2 M / 60 days ½ speed	$1.3 M / 60 days ½ speed
Miter Gate Machinery	$1.9 M / 30 days closed	Not Required	Not Required
Hydraulic System	$2.5 M / 30 days closed	Not Required	Not Required
Electrical System	$3.5 M / 60 days closed	Not Required	Not Required
Major Rehabilitation	$6.7 M / 0 days closed	$13.1 M / 45 days closed	$8.6 M / 45 days closed

Table ED 5-8. Individual Component Replacement Information versus Major Rehabilitation

Comparing the information provided for Cannelton in Table ED 5-8, it is clear that considerably less chamber closure time is required when comparing a major rehabilitation to individual component replacements. This makes sense given the fact that the major rehab is combining several different repairs into the same closures. In addition, the total cost is conservatively assumed to be approximately 10% less than the individual components since much less mobilization and demobilization is required when compared to replacing components individually. ORNIM was run for a major rehabilitation of the Cannelton main chamber and the results are shown in Figure ED 5-66. A summary of the results for the Cannelton main chamber are as follows:

Fix-As-Fails Average Annual Cost = $5.84 million
Individual Component Replacement Cost = $1.75 million
Optimized Major Rehab Date = $0.16 million

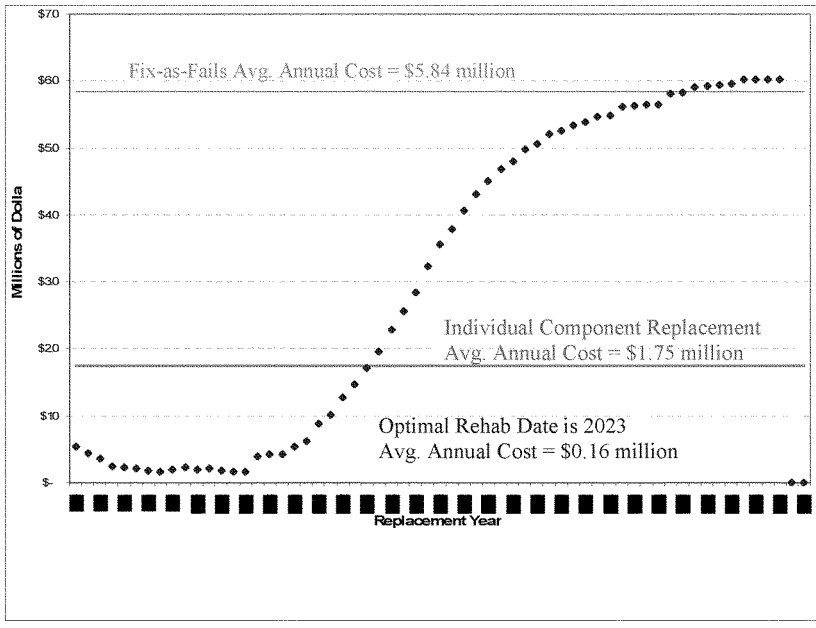


Figure ED 5-66. ORNIM Output for Cannelton Main Chamber Major Rehabilitation for the Clear Skies Traffic Forecast

The fix-as-fails represents the average annual total cost (repair and navigation impacts) of doing maintenance in a reactive mode, thus, replacing components after they fail. The individual component replacement average annual cost represents the total cost (repair and navigation impacts) of replacing the miter gates, culvert valves, miter gate machinery, hydraulic system, and electrical system all on their individual component optimized date, which is shown in the ORMSS overall summary table at the end of this section of the report. The date of 2023 represents the optimal replacement date for the major rehabilitation of the Cannelton main chamber for the lowest traffic scenario, which is the Clear Skies. The optimized dates for the major rehab of the main chamber at Cannelton for the other traffic forecasts are 2020 (Modified Clear Skies), 2017 (NAAQS), 2017 (Utility Based), and 2017 (Utility High). Although it is evident from Figure ED 5-66 that any year between 2017 and 20023 yields roughly the same average annual cost. ORNIM selects the absolute lowest cost option, but the randomness of the economic and engineering analysis is probably better indicated through the use of a curve fit or trend line. If that were done in this case, the optimal date for the major rehab would be roughly 2021 for all traffic projections. It is something to keep in mind when reviewing the results of the model and the intended accuracy of the analysis.

The optimization of major rehabilitations for other lock chambers is handled in the same manner. For a complete list of economically justified, optimally timed major rehabs refer to Section ED 5.10 which provides tables showing the economical results for individual component replacement and major rehabs for all projects as a part of ORMSS.

5.10 SUMMARY OF ECONOMIC ANALYSIS RESULTS

ORNIM was used to determine the economic justification of individual component replacement and major rehabs of all lock chambers on the Ohio River. Major rehabs were only analyzed when the components requiring replacement within the study period met the cost and construction criteria associated with current USACE major rehab guidance. There are five future traffic scenarios being evaluated within ORMSS: Clear Skies, Modified Clear Skies, NAAQS, Utility Based, and Utility High. For a more detailed description of each of these traffic scenarios, please refer to the Economics Appendix. The Engineering Team provided hazard rates to the Economics Team for the low, high, and middle traffic scenario for each component, as well as consequence event trees. ORNIM was then used to interpolate hazard rates between these values for the traffic scenarios where hazard rates were not provided. It is important to note that the high and middle scenarios vary at different projects due to characteristics associated with the traffic projections. The low scenario at each project was the Clear Skies scenario. The results for each project are shown in the individual tables within the Economics Appendix. If a component does not show up in the list, this means that a reliability analysis was completed for the project but no failures were encountered in the analysis and was not analyzed as an individual component in the economic analysis.

Section 6

LOCK CHAMBER COSTS AND CLOSURES NOT ASSOCIATED WITH RELIABILITY ISSUES

6.1 Background

This section describes the cost and closure schedules used in the formulation process for both the Without Project and With Project conditions. The cost and closure schedules are a series of spreadsheet matrices that detail lock chamber specific costs, closures, and other project costs for the time frame 2005 through 2065 for all 20 navigation projects on the Ohio River, although the economic analysis reports from 2010 and beyond. The schedules were essential in order to perform a complete economic analysis since maintenance levels vary between individual projects, as well as for different scenarios. The schedules consist of different types of closures, some of which are probabilistic-based and others that are fixed in the schedule. The various types of closures are detailed in the chapter of the Engineering Appendix. Matrices were developed according to each district's current maintenance program, as well as for multiple large-scale investment strategies. Maintenance programs vary considerably, as do available data between LRD districts due to different manpower availability, number of projects, differences in Operations accounting/record keeping methods, and project variability. In fact, maintenance for projects within the same district will vary due to the age and level of deterioration. This is covered in more detail within this section.

6.2 Cost and Closure Categories for Schedules

For the purposes of this report, this narrative will focus on the general categories of costs and closures associated with the matrices. There will be a detailed layout of how all the information was developed for a single lock to clearly describe the process of developing the information embedded within the cost and closure matrices. The same general process was used to develop the closure schedules for each lock.

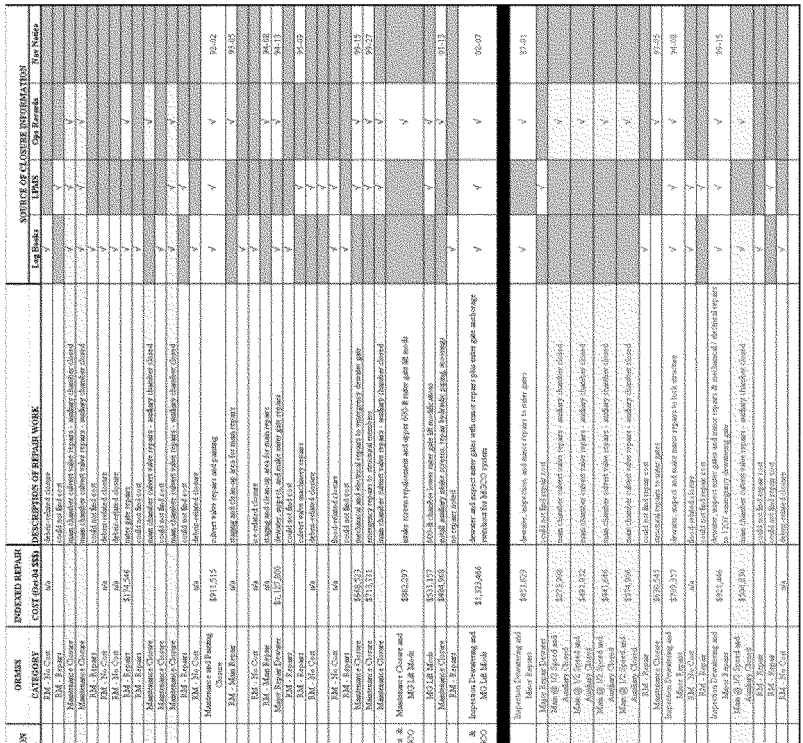
Closure of either an auxiliary or main chamber at a site can occur for a variety of reasons. Some closures are related to level of maintenance previously performed on the lock chamber, while others are not affected by maintenance history. In addition, some closures require repair costs, while others are not associated with repairs but are a function of weather, debris, or other non-repair related phenomena. This is more clearly explained within each category of closure. The categories and information used in the cost and closure matrices was based upon an extensive database search of historical records over roughly the last 20 years. The information was developed by reviewing historical records associated with the Corps of Engineers' Lock Performance Monitoring System (LPMS) data, Operations repair reports and field notes, Corps of Engineers Financial Management System (CEFMS) data, historical notices to navigation, and

finally, daily log books at the site. In general, the Operations repair reports coupled with historical navigation notices, as well as the on-site log books generally provided the most reliable set of historical data to draw from when developing the cost and closure information. In addition, the time frame for which this data was available has been around longer than the other sources of information, namely LPMS and CEFMS data. The LPMS and CEFMS data were also useful but variability among how project personnel from each site input the data required a more careful screening of the information. Each of these historical repairs was logged on a site-specific spreadsheet by lock chamber and then cross-referenced with the other databases. As noted earlier, the quality and availability of data varied considerably among the three districts, but overall, the ORMSS Engineering Team had a good amount of historic data to develop repair costs, categories of closures, and trends associated with the locks.

For clarity purposes, only one site will be detailed within this narrative in order to give the reader a detailed explanation of how the data was collected, categorized, and used in the analysis. The Cannelton Locks and Dam Project in the Louisville District was selected as a good example project to detail the development of the cost and closure information. The historical database collected and categorized for both the auxiliary and main lock chamber at Cannelton is shown in Table ED 6-1.

There is a lot of detailed information in Table ED 6-1. The detailed explanation of the categories is provided within this portion of the Engineering Appendix. The information in Table ED 6-1 reflects individual lock chamber closures in excess of 24 hours from 1988 through 2003 (16 years of data inclusive) at Cannelton. Any lock chamber closures less than 24 hours in duration were modeled within the economic transit delay curves. The top half of Table ED 6-1, shown in blue, reflects the historical closures for the Cannelton auxiliary chamber, while the bottom half of the table reflects historical main chamber closures. The historical main chamber closures are shown in red text. The right side of the table shows the various sources where the information was obtained. In some instances, multiple sources referenced the same historical closure. In these cases, check marks are shown for multiple sources. In general, navigation notices are only sent out for planned, lengthy duration closures. These closures typically had a detailed Operations report completed for them as well. Historical maintenance work related to main chamber culvert valves are highlighted in yellow. In these cases, the Louisville District repair fleet was set up in the existing auxiliary chamber while doing repairs to main chamber culvert valves. Thus, the auxiliary chamber was closed and main chamber was operating at ½ filling/emptying speed while repairs were being made.

As noted earlier, Nav Notices and Ops Records were only available for planned, lengthy duration closures. Therefore, Random Minor closures did not have this type of information. These Random Minor closures had to be separated into ones that required repair and those that were weather related. If the LPMS database indicated that the closures was for "debris in lock", "flood", "ice", or other weather-related, then it was classified as a *Random Minor No Repair* closure. If LPMS coding showed "Test/Maint" or "Other" then it was categorized as *Random Minor Repair Required*, unless it was known to fall into the major maintenance category where typically Operations repair records and navigation notices also referenced the closure. A detailed explanation of each of the lock chamber closure categories is provided following Table ED 6-1.



DATE	Begin Time	End Date	End Time	LOCK	CHAMBER	LPMS STARTUP	LPMS CLOSURE CLASSIFICATION	DURATION (DAYS)	ORMES CATEGORY	PROPOSED REPAIR COST (fm-ba SSS)	DESCRIPTIONS OF REPAIR WORK	NOTICE OF CLOSURE INFORMATION			
												Log Books	LPMS	Ops Records	Run Notes
7/9/1988	730	7/31/1988	2005	Cannelton	Auxiliary	S	Debris in Lock	2.54	BM - Inc Cost	n/a	blinds-related closure	√			
8/29/1989	1815	9/10/1989	738	Cannelton	Auxiliary	T	Tow / Maint	1.51	BM - Repair		could not find cost		√		
4/26/1990	2130	5/9/1990	1000	Cannelton	Auxiliary	Culvert Valves	Main - 15 qtr. Ave - close	12.33	Maintenance Closure		main chamber culvert valves repairs - auxiliary chamber closed	√	√	√	
5/10/1990	1000	5/31/1990	2130	Cannelton	Auxiliary	Culvert Valves	Main - 15 qtr. Ave - closed	21.46	Maintenance Closure		main chamber culvert valves repairs - auxiliary chamber closed	√	√	√	
9/17/1990	730	9/17/1990	1730	Cannelton	Auxiliary	T	Tow / Maint	0.83	BM - Repair		could not find cost	√			
10/3/1990	1930	10/17/1990	1730	Cannelton	Auxiliary	S	Debris in Lock	14.00	BM - Inc Cost	n/a	debris-related closure	√			
10/27/1990	700	10/29/1990	415	Cannelton	Auxiliary	S	Debris in Lock	3.89	BM - Inc Cost	n/a	debris-related closure	√			
5/11/1991	1500	5/20/1991	1515	Cannelton	Auxiliary	S	Other	9.01	BM - Repair	$134,546	gates gate repairs		√		
6/27/1991	1530	7/2/1991	1500	Cannelton	Auxiliary	T	Tow / Maint	4.98	BM - Repair		could not find cost	√			
6/5/1996	0	6/5/1996	0	Cannelton	Auxiliary	Culvert Valves	Main - 15 qtr. Ave - close	15.00	Maintenance Closure		main chamber culvert valves repairs - auxiliary chamber closed		√		
12/5/1991	1530	2/24/1992	820	Cannelton	Auxiliary	S	Other	36.33	Maintenance Closure		could not find cost	√			
3/5/1992	900	6/30/1991	700	Cannelton	Auxiliary	Culvert Valves	Main - 15 qtr. Ave - close	28.12	Maintenance Closure		main chamber culvert valves repairs - auxiliary chamber closed	√			
8/4/1991	1900	8/9/1991	200	Cannelton	Auxiliary	S	Debris in Lock	5.04	BM - Inc Cost	n/a	could not find cost	√	√	√	
12/9/1991	700	12/11/1991	1600	Cannelton	Auxiliary	S	Debris in Lock	3.04	BM - Inc Cost	n/a	debris-related closure	√			
9/2/1992	230	7/9/1992	2130	Cannelton	Auxiliary	T	Tow / Maint	37.81	Miscellaneous - not listed Closure	$911,515	culvert valve repair and painting	√	√	√	92-02
4/7/1993	0	4/7/1993	0	Cannelton	Auxiliary	T	Tow / Maint	0.00	BM - Main Repair	n/a	fittings and miter-sill gate for main repair				
5/6/1993	1100	5/6/1993	1100	Cannelton	Auxiliary	T	Tow / Maint	0.00	BM - Repair		could not find cost		√	√	93-05
5/6/1993	600	5/26/1993	1100	Cannelton	Auxiliary	T	Tow / Maint	20.21							
10/27/1994	800	10/31/1994	2100	Cannelton	Auxiliary	H	Ice	4.04	BM - Inc Cost	n/a	ice-related closure		√		
3/8/1994	0	3/7/1994	0	Cannelton	Auxiliary	T	Tow / Maint	0.00	BM - Main Repair	n/a	engine and miter-sill gate for main repairs				
7/11/1994	0	7/11/1994	0	Cannelton	Auxiliary	T	Tow / Maint	0.00	Major Repair Recovery	$3,100,000	could not find cost - miter gate repairs	√	√	√	94-15
7/11/1994	0	7/13/1994	2300	Cannelton	Auxiliary	R	Lock Machinery Malfunction	2.96	BM - Repair		culvert valve machinery repair				95-05
5/11/1995	0	5/11/1995	1500	Cannelton	Auxiliary	T	Tow / Maint	0.00	BM - Repair		could not find cost	√	√	√	
11/9/1994	1500	12/1/1994	2400	Cannelton	Auxiliary	S	Debris in Lock	14.19	BM - Inc Cost	n/a	debris-related closure	√	√	√	
10/31/1994	2100	11/9/1994	1500	Cannelton	Auxiliary	S	Debris in Lock	8.67				√	√	√	
10/31/1994	700	10/31/1994	2300	Cannelton	Auxiliary	T	Tow / Maint	15.67	BM - Inc Cost	n/a	flood-related closure				
12/21/1997	0	5/29/1997	2300	Cannelton	Auxiliary	T	Tow / Maint	2.96	BM - Repair		could not find cost	√	√	√	
7/9/1999	2130	7/29/1999	1130	Cannelton	Auxiliary	T	Tow / Maint	20.38	Maintenance Closure	$656,523	mechanical and electrical repairs to miter-sill dewater gate		√	√	99-15
11/5/1999	0	11/15/1999	2330	Cannelton	Auxiliary	T	Tow / Maint	10.99	Maintenance Closure	$713,321	emergency repairs to structural members		√	√	99-27
11/11/1999	0	11/29/1999	0	Cannelton	Auxiliary	Culvert Valves	Main - 15 qtr. Ave - close	9.08	Maintenance Closure		main chamber culvert valves repairs - auxiliary chamber closed		√	√	
9/24/2006	0	6/29/2000	0	Cannelton	Auxiliary	T	Tow / Main	11 days Maint @ 20 days MSRV	Maintenance Closure and M&R Lat Mods	$992,297	gate: convex replacement and apex 6'6 & miter gate lift cords		√	√	
3/9/2000	1230	3/9/2000	1500	Cannelton	Auxiliary	S	Other	3.95	M&R Lat Mods	$533,127	6'6 & chamber convex gate lift modifications				
7/11/2001	0	8/18/2001	0	Cannelton	Auxiliary	T	Tow / Maint	28.96	Maintenance Closure	$484,968	install auxiliary gate controls, repair hydraulic piping, drawings		√	√	01-13
5/15/2002	0	5/15/2002	2300	Cannelton	Auxiliary	T	Tow / Maint	6.96	BM - Repair		lock repairs noted	√			
7/8/2003	0	7/30/2003	2300	Cannelton	Auxiliary	T	Tow / Maint	19 days Dft. & 13 days MSRV	Impressa Pavement and M&R Lat Mods	$1,323,466	Jamester and impact miter gate; with minor repairs plus miter gate anchorage residuals for M&R/O system	√	√	√	03-07
6/29/1987	1400	7/8/1987	1130	Cannelton	Main	T	Tow / Maint	8.89	Impression Pavement and Major Repair	$403,629	Jamester, inspection, and minor repairs to miter gates	√		√	87-01
7/22/1988	1230	8/31/1988	1400	Cannelton	Main	T	Tow / Maint	31.09	Major Repair Recovery		could not find repair cost		√		
4/26/1995	1230	5/24/1995	1900	Cannelton	Main	Culvert Valves	Main - 15 qtr. Ave - close	14.13	Main @ 15' Speed and Auxiliary Closed	$273,995	main chamber culvert valves repairs - auxiliary chamber closed		√		
7/5/1989	2230	7/20/1989	1615	Cannelton	Main	Culvert Valves	Main - 15 qtr. Ave - close	22.79	Main @ 15' Speed and Auxiliary Closed	$493,012	main chamber culvert valves repairs - auxiliary chamber closed		√		
6/4/1993	0	6/21/1993	0	Cannelton	Main	Culvert Valves	Main - 15 qtr. Ave - close	16.96	Main @ 15' Speed and Auxiliary Closed	$443,846	main chamber culvert valves repairs - auxiliary chamber closed		√		
3/5/1993	300	3/5/1993	2400	Cannelton	Main	Culvert Valves	Main - 15 qtr. Ave - close	29.17	Main @ 15' Speed and Auxiliary Closed	$574,394	main chamber culvert valves repairs - auxiliary chamber closed		√		
4/29/1992	1330	4/30/1992	1600	Cannelton	Main	T	Tow / Maint	2.12	BM - Repair		could not find repair cost	√			
4/25/1995	0	5/5/1995	0	Cannelton	Main	T	Tow / Maint	9.00	Major Repair Recovery	$626,581	recorded repairs to miter gates		√		95-05
3/17/1994	730	5/26/1994	1600	Cannelton	Main	T	Tow / Maint	9.12	Impression Pavement and Major Repair	$799,377	Jamester, inspect and repair miter gate hoist structure	√	√	√	94-08
3/5/1997	930	3/15/1997	1600	Cannelton	Main	T	Tow	0.28	BM - Inc Cost	n/a	flood-related closure	√			
11/15/1999	30	11/17/1999	1245	Cannelton	Main	S	Other	1.51	Risk - Repair		could not find repair cost	√	√		
7/29/1999	1200	8/7/1999	1230	Cannelton	Main	T	Tow / Maint	9.01	Impression Pavement and Major Repair	$927,446	Jamester, inspect miter gates and minor repairs & mechanical / electrical repairs	√	√	√	99-15
11/15/1999	0	11/29/1999	0	Cannelton	Main	Culvert Valves	Main - 15 qtr. Ave - closed	9.08	Main @ 15' Speed and Auxiliary Closed	$564,870	main chamber culvert valves repairs - auxiliary chamber closed	√		√	
9/1/2001	0	9/5/2001	2300	Cannelton	Main	T	Tow / Maint	3.96	Risk - Repair		could not find repair cost		√		
12/16/2003	0	12/17/2003	1300	Cannelton	Main	S	Other	1.72	Risk - Repair		could not find repair cost	√			
12/20/2005	0	2/3/2006	2300	Cannelton	Main	S	Emergency Lock	5.96	BM - Inc Cost	n/a	debris-related closure	√			

Table ED 6-1. Cannelton Historical Cost and Closure Information

For the purposes of this study, chamber closures were broken down into three major categories with several sub-categories within each major category. The three major categories of closures are **Random Minor, Maintenance**, and **½ Speed Filling and Emptying Events**. The various sub-categories within each major category are described along with how these closures were scheduled in the matrices. The indexed cost feature of the table was to get all costs to current dollar levels for a consistent approach with other aspects of the study. The costs were indexed using the USACE indexed costs system for civil works structures.

Major Category - Random Minor. Random minor closures are closures that are essentially independent of historical maintenance or replacement/rehabilitation work. These involve down time due to items that are considered unavoidable. Lock chambers are sometimes closed for unforeseen occurrences regardless of historical level of maintenance. Examples of this type of closure would be shutting down the auxiliary chamber to flush ice or debris through the project or weather-related closures (fog, snowstorm, etc...). Some of these can be rather lengthy, but by definition the Engineering Team capped Random Minor closure durations at 15 days since most data supported these closures did not exceed this limit. The Economics Team captures all closures that are less than 24 hours in duration when they develop their chamber-specific transit delay curves for the economic analysis. Anything over 24 hours in duration is captured by the Engineering Team and used in the development of the cost/closure schedules. Some random minor closures require physical repairs and others, such as weather-related closures, require no repairs at all. The Economics Team develops transit delay curves for closure durations of various lengths, so all the closures under this category were rounded off to the nearest transit delay curve duration evaluated by the Economics Team. There are 10 Random Minor closure types as listed below and all closures projected in these categories through the study period (2010 through 2070) were based upon historical trends.

15-day without repair costs
10-day without repair costs
5-day without repair costs
3-day without repair costs
1-day without repair costs

15-day with daily repair cost rate
10-day with daily repair cost rate
5-day with daily repair cost rate
3-day with daily repair cost rate
1-day with daily repair cost rate

The daily repair cost rate was determined based upon all the known Random Minor closures throughout a district where good cost data was available, averaged across the district, and then used for all Random Minor closures with costs throughout that district. For example, the 20-year database for Louisville District locks indicated that the daily repair costs averaged roughly $21,000 per day when indexed to current dollar levels. The Random Minor repair rates for Huntington and Pittsburgh Districts were

$33,000 per day and $35,000 per day, respectively, for these types of closures. Differences in rates between districts are normal since each district does maintenance differently, has a different number of projects, and different manpower/equipment. The Ohio River Navigation Investment Model (ORNIM) handles the Random Minor projected closures and costs by assigning a probability of occurrence that is kept the same in each year of the study period. Thus, each of the Random Minor categories listed above was determined how often to occur over the last 20 years and then a percentage chance of occurrence was applied to each event. The district-specific daily repair fleet cost was the same for both the main and auxiliary chambers for Random Minor closures.

Major Category - Maintenance. There are multiple categories of maintenance closures and many are a function of age and use. The categories were developed after conducting the research on the historical databases across each district. As can be expected, the older and high use projects are closed more often for maintenance. In addition, each district had many differences compared to other districts. In fact, maintenance closure schedules and costs vary at projects within the same district according to site-specific problems. This is particularly true at the older projects on the Ohio River that have not been rehabilitated (Markland, Greenup, and Meldahl). Many of the features of a lock and dam deteriorate with time and use. These features require more frequent maintenance in order to keep them operational. Some of these features (miter gates, operating machinery, etc...) require the lock chamber to be closed in order to perform maintenance.

There are seven sub-categories of Maintenance repairs. Not all of the sub-categories require a chamber closure as some work involves culvert valves which have maintenance done on them while a chamber is open to traffic. A brief description of each category is provided in this narrative.

The costs and durations of many of these repairs are dependent upon whether or not they are occurring in the main or auxiliary chamber. It was noted during the research of historic data that for some districts the daily repair fleet costs for maintenance closures varies according to which chamber is down for repairs. For example, major maintenance main chamber repairs for Louisville District locks averaged roughly $67,000 per day when indexed to current dollar levels. The auxiliary chamber closures only averaged $31,000 per day for major repairs. The primary difference for this is the need to get main chambers open to navigation traffic as soon as possible. Additional staff is provided and repairs requiring main chamber closures are prepared far in advance with a lot of labor done prior to the closure. Table ED 6-3 shows the maintenance events within the Louisville District upon how these daily fleet rates were established.

All this means that the cost is high, but the closure duration is kept as short as possible, thus, increasing the daily repair cost since all the prepatory work is also charged to the same repair project. The auxiliary chamber daily operating costs are lower because the repair fleet can afford to sit in the auxiliary chamber for longer and make multiple repairs over the entire project. For example, intake screens for both main and auxiliary chambers recently required replacement at the Louisville District projects and the repair fleet was stationed in the auxiliary chamber during these repairs. While the cost did not necessarily go up, the number of days was increased, thus, a lower daily rate for auxiliary chamber maintenance repairs.

SUMMARY OF LOUISVILLE DISTRICT LOCK CHAMBER MAINTENANCE FLEET COSTS

	1200-FT CHAMBER INFORMATION				600-FT AUX. CHAMBER INFORMATION	
LRL Project	# of 1200-ft Closure Events	Avg. Fleet Cost for 1200-ft Closures	# of 1/2 Speed Fill/Empty Events	Avg. Fleet Cost for 1/2 Speed	# of Auxiliary Closure Events	Average Fleet Cost for Auxiliary Closures
Markland	7	$50,634	1	$23,404	6	$22,728
McAlpine	5	$58,392	3	$12,302	auxiliary chamber being replaced	
Cannelton	4	$75,146	5	$25,933	7	$30,308
Newburgh	4	$54,575	none noted	n/a	3	$34,697
John T. Myers	5	$78,012	3	$27,903	3	$42,827
Smithland	6	$85,667	1	$13,465	both chambers are 1200-ft	
	31		13		19	
WEIGHTED AVERAGES		$66,753 per day 1200-ft chamber closure		$22,088 per day 1/2 speed F/E operations		$30,584 per day of auxiliary chamber closure
		USE $67,000		USE $22,000		USE $31,000

Table ED 6-3. Computations of LRL Daily Fleet Rates from Historical Data

Maintenance Subcategory - Inspection and Minor Repairs. These are relatively short-duration closures (between 10 and 15 days) that are effective at helping districts asses the general condition of their structures, as well as identify potential major problems before they lead to significant failures. These closures vary by district according to their maintenance policy, but they require the repair fleet to travel to the site, dewater the lock chamber, inspect significant structures, make quick repairs as necessary, and then put the chamber back in service. The daily fleet repair rate for each district applies to these closures. They are "hard-wired" into the analysis according to each district's maintenance policy and their frequency. A more aggressive inspection and minor repair frequency is required at aging sites where problems need more attention. The daily rates for main chamber and auxiliary chamber repairs under this category were $67,000/day and $31,000/day, respectively, for Louisville District locks.

Maintenance Subcategory - Major Gate Repairs. These closures are lengthy maintenance closures for repairs to miter gates. Historically, miter gate repairs cause some of the lengthiest closures in terms of chamber down time. These closures are for major repairs to miter gates and typically include replacing pintles, repairing cracks in the gates, quoin and miter block repairs, etc. The duration of these closures typically exceed 30 days. The chamber-specific daily repair fleet rate for the district is applied to these closures. The frequency of these closures is dependent upon the historic age and use of the project. The frequency and duration of major gate repair closures will change to less closures, less frequently following a major rehab and/or lock extension. The daily rates for main chamber and auxiliary chamber repairs under this category were $67,000/day and $31,000/day, respectively, for Louisville District locks.

Major Subcategory - Miter Gate Changeout Modifications. This category is to retrofit miter gates for the a miter gate changeout system. This category is only applicable to the Louisville and Huntington District locks. Miter gate modification requirements include retrofitting the gates to make them liftable for switchout by the gatelifter crane. These modifications to make them liftable are generally short in nature and most have already been completed for the Louisville District sites with the exception of Smithland where there already are twin 1200-ft lock chambers. The other modification requires changes to the anchorage system. These changes will also make the switchout of the gates much easier once they have been completed. The anchorage

changes require two lengthy (30 to 45-day events) in order to modify both sets of miter gate anchorages for the switchout system. These are one-time repairs and once completed are not required again. The chamber-specific daily repair fleet rate for the district is applied to these closures. The daily rates for main chamber and auxiliary chamber repairs under this category were $67,000/day and $31,000/day, respectively, for Louisville District locks.

Major Subcategory - General Maintenance Repair. This repair is for lock chamber maintenance requiring closure, but not related to miter gate repairs. In researching the historical database, these repairs occur once or twice in a 20-year cycle for the main chamber and much more frequently for the auxiliary chamber. The primary reason that the auxiliary chambers see more of these types of closures is that the district repair fleet will safely "park" in the auxiliary chamber while making repairs to other structures on the facility. For example, the intake screens for the filling and emptying system require the repair fleet to make repairs at select times around traffic. This is a lengthy project but doesn't necessarily shut the main chamber down for any extended period during repairs. However, the fleet will park in the auxiliary chamber during this time, thus, completely shutting it off from traffic. The auxiliary chamber provides a safe location for setting the fleet away from navigation and the outside of the approach walls where it is exposed to currents associated with the dam. The chamber-specific daily repair fleet rate is applied to these closures. The daily rates for main chamber and auxiliary chamber repairs under this category were $67,000/day and $31,000/day, respectively, for Louisville District locks.

Maintenance Subcategory – Emergency Repairs. This subcategory is becoming ever more common for the infrastructure on the Ohio River. Aging locks coupled with increased traffic load with tight O/M budgets means that more frequent maintenance closures are required to keep the system operational. These closures are not necessarily "unscheduled" in the truest sense of the word, but they are reflective of the required level of maintenance beyond what is considered normal for locks that are in good, reliable condition. They are a good indicator that the components are reaching the end of their economic service life and are in need of rehabilitation or replacement. For example, the Markland main chamber miter gates are in such poor condition that the Louisville District repair fleet is required to dewater the lock every 1 to 2 years in order to reduce the chance of catastrophic failure of these gates. Typically, dewaterings for inspections and repairs are done every 5 years, thus, many of these closures fall into the Emergency Repairs subcategory because they are way beyond normal O/M requirements. In this example, the repairs on the 5-year interval fall into other categories (Inspection & Minor Repairs and Major Gate Repairs) because that is typical practice for Louisville District locks on the Ohio River that are in good condition.

Major Category – ½ Speed Filling and Emptying Events. Culvert valve repairs were also separated into an individual category to determine how often and for how long the main chamber operates at ½ filling and emptying speed. Decreased filling and emptying times only occur due to valve repairs only occur for 1200-ft chambers on the Ohio River because the shorter, auxiliary chambers only have a single filling valve and single emptying valve. Thus, any repairs to valves on the auxiliary chambers requires them to be closed. The ORMSS Economics Team captures this reduce processing time through the facility by computing specific transit delay curves for ½ speed operating

periods of various durations. All historical data was evaluated to determine which ½ speed transit delay curve durations the Economics Team had to develop. All projected ½ speed operations are rounded to the closest duration evaluated by the Economics Team.

Most times the repair fleet is stationed in the auxiliary chamber while these main chamber valve repairs are made since this does not cause a main chamber closure only a slower filling and emptying time. As shown in Table ED 6-3, it was determined the costs of these repairs average $22,000 per day. This is due to having a smaller repair crew completing valve repairs as compared to major miter gate repairs. There are two types of ½ speed filling and emptying events that need to be considered when evaluating this in the economic analysis. The first is when the repair fleet is stationed in the auxiliary chamber while the main chamber continues to operate at ½ speed as valve repairs are made. The second is when the auxiliary chamber remains open while valves in the main chamber are repaired.

6.3 Other Costs

The various types of maintenance closures and repairs affecting transit time were covered in detail in Section 6.2 of this narrative. In addition, there are other costs to operate the project beyond those associated with maintenance closures. These are detailed below.

Other Project Costs. In order to determine the overall cost to operate the project, non-lock maintenance costs had to be captured in the schedules. Included in these costs are items such as daily operations and minor maintenance costs, recapitalization costs associated with the dam portion of the project, and dredging costs.

The daily operations and minor maintenance costs were developed by tracking them for five consecutive years for each project and updating them to current dollar levels. The daily operations and minor maintenance costs include categories such as USACE on-site labor, overhead, equipment, and minor maintenance (including project contracts such as grass mowing and minor painting). These are assumed to be the same for all scenarios as they are not a function of the maintenance scenarios being evaluated. Each site has different costs since manpower costs vary as does the equipment at each site and the need for varying types of contracts (such as the amount of grass mowing required). Dredging costs directly associated with each project are also included in these annual costs.

Separate large scale dam recapitalization costs are projected for only major work such as replacement of dam gates or complex replacement and repair to the stilling slabs below the gates. These are projected out separately because the investment required to make these repairs is beyond the scope of normal O/M and most likely would require a major rehabilitation funds to be provided. Other more routine dam maintenance costs are captured within the daily operations and minor maintenance category. For this ORMSS report, it was assumed that dam gates would need to be replaced after 75 to 80 years of service as part of a major rehabilitation project unless a particular site warranted earlier replacement. Previous instrumentation and inspection of the dam gates indicate that no gate systems themselves are in such poor condition that this is not an adequate assumption.

If a major rehabilitation of a dam structure is required before the 75-80 year period, then justification is provided within each schedule. For example, the dam at J.T. Myers will not be 75 years old until approximately 2050, however, a major rehabilitation study for that dam is scheduled for completion in 2006. The primary purpose of the rehabilitation is erosion of the stilling basin below the dam gates that are in need of repairs beyond normal O/M. A secondary reason for the rehabilitation study of the J.T. Myers dam is to install anchors to meet stability requirements. Both of these costs are embedded in the dam portion of the cost/closure schedule at J.T. Myers and spread over the years as detailed in the J.T. Myers Dam Major Rehab report. The current estimate for completing the rehabilitation of the J.T. Myers Dam is approximately $33 million. It is assumed to be spread evenly over three years since stilling basin slab repairs can only be done in low water season.

The stilling basin erosion is a problem at several Ohio River projects, most notably on the middle and lower Ohio River. One of the structures required to make repairs to the stilling basins is a specialized dewatering bulkhead that is included within the J.T. Myers Major Rehab. This bulkhead can be used at other sites with site specific adapters that could be included as part of any rehabilitation project involving stilling basin slab repairs. Projects with known erosion problems will have their repair costs embedded following the J.T. Myers major rehabilitation assumptions and prorated for the number of gate bays. Also, the procurement cost of the dewatering bulkhead will be stripped out of the estimate since it will already be procured as a part of the J.T. Myers Dam Rehab. These repairs and their costs are incorporated at each site as indicated in the cost/closure schedules. It is important to note that the rehab options are the same for all scenarios being evaluated and are incorporated to capture a more accurate reflection of the expected long-term costs to operate the system.

6.4 Projecting Future Costs and Closures

There are two basic scenarios that the Engineering Team had to project future cost/closure schedules for as a part of ORMSS. The first scenario can be considered as a baseline option where the historical maintenance pattern is projected into the future and then increased maintenance is required as the structure continues to age. This pattern is based upon the historical data supporting increased maintenance needs for the older projects on the Ohio River that have not been rehabilitated (Markland, McAlpine, Greenup, Meldahl, New Cumberland, and Pike Island). The second scenario will be the improved maintenance schedule following either a major rehabilitation or large-scale improvement (auxiliary lock extension and/or new lock chamber for EDM). Once a major rehab or large-scale capacity improvement is made it is assumed that the chamber returns to a much improved maintenance scenario since all the unreliable features have been replaced as necessary.

Baseline Maintenance Schedule. One of the primary purposes and outputs of the ORMSS is the long-term investments in infrastructure required of the system in order to keep it a safe and reliable transportation link. The more age and operating cycles that the infrastructure sees, the more cumulative damage occurs to the structure. This is evident from the historical database search of the last 20 years of maintenance costs and

closures. Focusing in on the Louisville District as an example, it is evident that their older facilities (Markland and McAlpine) require more frequent maintenance closures than the newer facilities (Smithland). Most of these additional closures show up under the "Emergency Closures" and "Main @ ½ Speed with Auxiliary Closed" subcategories. This is clearly shown in Table ED 6-3 for all of the Louisville District locks for the years 1987-2004 (inclusive). The maintenance for 2005 and 2006 are projected based upon best estimates of the Louisville District Operations Division in order to get a 20-year cycle to work from (see footnote to table).

Based upon the historical information provided in Table ED 6-3, general patterns regarding maintenance needs can be developed as a guide for projecting future maintenance needs at other high traffic locks. The future maintenance schedule for the Louisville District projects is shown in Figure ED 6-1.

Historical Data from 1987- 2004 from LPMS, CEFMS, Log Books, Operations Records, and Navigation Notices

		1200-FT CHAMBER CLOSURE TYPES AND FREQUENCY					
PROJECT	OPERATIONAL	Inspection & Minor Repairs	Maintenance Repairs	Emergency Closures	Major Gate Repairs	Main @ 1/2 Speed with Aux. Closed	Main @ 1/2 Speed with Aux. Open
Markland	1958	10,10		10,15,10, 15*, 15*	30,45	45,90	
McAlpine	1964	15,15	30	15,10	45	45,45,90	
Cannelton	1972	10,10,10		10	30, 30*	30,30,30,30,30	30*
Newburgh	1975	10,10	10		45, 30*		45*, 30*
John T. Myers	1975	15,10,15	10		45	30,45	45
Smithland Land	1979	10,10,15	10		30	not applicable	30
Smithland River	1979	10,10	10		30	not applicable	
		600-FT AUXILIARY CHAMBER CLOSURE TYPES AND FREQUENCY					
PROJECT	OPERATIONAL	Inspection & Minor Repairs	Maintenance Repairs	Emergency Closures	Major Gate Repairs	Auxiliary Closed & Main @ 1/2 Speed	Maintenance & Painting
Markland	1958	15, 15*	15,15,10,30,10,30	45,60	45,30	45,90	90
Cannelton	1972	10	30,60,45,30,10,30	10	30	30,30,30,30,30	45
Newburgh	1975	10	30*		60		60
John T. Myers	1975	15	30		30,45	30,45	

* Note: In order to get a 20-year cycle, maintenance for the years 2005 and 2006 are needed. The Louisville District plans its major repairs with detailed schedule 2 years in advance, thus, the closures planned for 2005 and 2006 are fairly well defined from a planning standpoint. Therefore, these planned clos will be included in the analysis to get a more accurate reflection of a 20-year cycle.

Table ED 6-3. Historical Maintenance Closure Types for LRL Lock Chambers

The schedule shown in Figure ED 6-1 represents expected closure patterns based upon ages of the locks. Since all of the Louisville District projects are high traffic locks and none have been rehabilitated in the past, this schedule is applicable for all LRL projects. The starting point for particular maintenance types is set based upon the 2005/2006 LRL maintenance schedule or the most recent event prior to this date. The schedule of projected closures for a lock chamber varies according to the age of the project.

As shown in Figure ED 6-1, the schedule was developed around a 20-year operating cycle. This cycle was developed by taking all the sound data from various sources up through 2004. In general this provided about 18 years or so of good information to draw from in terms of establishing applicable patterns. Projected maintenance for the years 2005 and 2006 were used to complete the 20-year patters since most of these closures require long lead times and are pretty much set unless other issues arise. Every type of maintenance closure is rolled into the 20-year cycle with the exception of the "Emergency Closure" subcategory. This subcategory is based upon the operating age of the structure and not the 20-year cycle.

20-YEAR CYCLE CLOSURE INFORMATION BY CATEGORY FOR LOUISVILLE DISTRICT	
INSPECTION & MINOR REPAIRS CATEGORY	
Main Chamber	3 events (10, 15, and 10-day THEN alternate to 15, 10, and 15-day). All at $67,000 per day of closure
Aux. Chamber	1 event in 20-year cycle (alternate between 10 and 15 days for each cycle) @ $31,000 per day of closure
MAINTENANCE REPAIR CATEGORY	
Main Chamber	1 event (varies between 10 and 30 days) @ $67,000 per day of closure
Aux. Chamber	Stage 1 will be for until an auxiliary lock reaches 25 years, a single 30-day closure @ $31,000 per day
	Stage 2 will be after a project reaches 25 years, 6 closures varying between 10 and 60 days @ $31,000 per day
EMERGENCY REPAIR CATEGORY	
Main Chamber	Stage 1 will be until the lock reaches 30 years in age, no events in 20-year cycle
	Stage 2 will be for lock between 31 and 50 years in age, assume 3 events (10, 15, and 15-day) @$67,000 per day
	Stage 3 will be for lock between 51 and 70 years in age, assume 5 events (15, 30, 15, 30, and 15-day) @$67,000 per day
	Stage 4 will be for lock over 70 years, every other year on a 15, 30, and 45-day pattern @$67,000 per day
Aux. Chamber	Stage 1 will be until the lock reaches 30 years in age, no events in 20-year cycle
	Stage 2 will be for lock between 31 and 50 years in age, assume 2 events (10 and 30-day) @$31,000 per day
	Stage 3 will be for lock between 51 and 70 years in age, assume 4 events (15, 30, 45, and 60-day) @$31,000 per day
	Stage 4 will be for lock over 70 years, every other year on a 30 and 45-day pattern @$31,000 per day
MAJOR GATE REPAIR CATEGORY	
Main Chamber	Assume 1 to 2 every 20 years depending upon beginning date. Duration will alternate between 30 and 45 days.
Aux. Chamber	Assume 1 to 2 every 20 years depending upon beginning date. Duration will alternate between 30 and 60 days.
MAIN CHAMBER @ 1/2 SPEED WITH AUXILIARY CHAMBER CLOSED CATEGORY	
Main Chamber	3 events varying between 30, 45, and 90 days at $22,000 per day of Main Chamber @ 1/2 speed operation.
Aux. Chamber	Same events as shown in Main Chamber except the Auxiliary Chamber is closed
MAIN CHAMBER @ 1/2 SPEED WITH AUXILIARY CHAMBER OPEN CATEGORY	
Main Chamber	1 event varying between 30 and 45 days @ $22,000 per day of Main Chamber @ 1/2 speed operation
Aux. Chamber	This category does not affect auxiliary chamber
MAINTENANCE & PAINTING CATEGORY	
Main Chamber	This category does not affect main chamber based upon historic data
Aux. Chamber	1 event that varies between 45 and 90 days

Figure ED 6-1. Projected Maintenance Schedule for Louisville District Locks

Improved Maintenance Scenario. An improved maintenance scenario under ORMSS means that either a major rehabilitation or large-scale capacity improvement (lock extension/new lock) has taken place and the deteriorated lock that was rehabbed or replaced no longer needs additional closures beyond what history has shown to be "typical" frequencies and durations for reliable locks. The improved maintenance scenario contains much less maintenance closures than those associated with an aged and deteriorated project. This is because it is assumed all unreliable features would be replaced or substantially improved such that the lock can be returned to a maintenance schedule that is more reflective of a "reliable" lock. Therefore, there are no emergency closures in the cost/closure schedule following a major rehabilitation or large-scale capacity improvement. In addition, there would be no increased "general maintenance repairs" for auxiliary chambers that are required for older auxiliary lock chambers. The improved maintenance scenario means that the lock that is rehabilitated or extended moves back to a Stage 1 condition (see Figure ED 6-1) following the rehab/extension. The other categories of maintenance closures (with the exception of miter gate changeout modifications) are included in the improved maintenance scenario following a major rehabilitation or lock extension/new lock. The improved maintenance scenario is input into the ORNIM analysis after a major rehab is analyzed in the model. ORNIM tests different rehabilitation dates in the analysis and "slides" maintenance closures around to determine the optimum mix of maintenance with reliability. All maintenance up to the date of the major rehab uses the baseline maintenance scenario within the analysis.

Section 7

WITH PROJECT CONCEPTUAL DESIGNS AND COSTS FOR LARGE-SCALE IMPROVEMENTS

7.1 INTRODUCTION

One of the primary engineering inputs to the overall economic analysis is conceptual cost estimates for increasing capacity at select projects where lengthy delays to the navigation industry can occur during main chamber closures. These lock chamber closures can occur due to a variety of reasons and are better described in Section 6 of this appendix. The primary point is that the engineering team was required to develop conceptual capacity improvement designs and cost estimates at select projects that indicated a capacity issue during the study period. This was done to support the overall economic and environmental analysis being done as part of the ORMSS SIP. The large-scale capacity improvements designs primarily involved either new lock chambers or extensions of existing auxiliary lock chambers to a nominal length of 1200 feet. For most cases, multiple levels of large scale improvements were considered as part of this analysis. For example, the lock extension option has multiple subcomponents that were varied including approach wall lengths and supplemental filling/emptying systems.

The level of detail in terms of designs and cost estimates is only conceptual because the ORMSS SIP is not authorizing any project improvements. The end result of the ORMSS SIP will be a master investment plan that will provide a template for future studies and project needs to maximize the multiple uses of the Ohio River including navigation infrastructure investments. However, many of the same design features and corresponding unit prices being used are currently being implemented as part of recent Ohio River lock projects either under construction (Olmsted, McAlpine) or in detailed design (Greenup, J.T. Myers). Therefore, they will be utilized as part of the ORMSS SIP conceptual capacity improvement designs and cost estimates. This information will be utilized to the greatest extent possible. General site-specific information will be used to modify the J.T. Myers and Greenup designs where warranted such that major site-specific differences, such as rough estimates for quantities, will be included as part of the ORMSS SIP analysis for the With Project comparisons.

In general, there are two types of projects on the Ohio River where the main chamber is 1200-ft and the auxiliary chamber is 600-ft. The first is representative of many of the projects on the lower river (Newburgh) where there are 6 laterals for filling and emptying the existing auxiliary lock chamber. For these types of projects, the conceptual designs and costs for Newburgh will be detailed in this narrative. The other type is similar to the Meldahl project where higher pool differentials required 11 laterals to fill and empty the lock chamber. These types of projects will be considered representative by Meldahl with respect to this narrative.

The other sites under consideration for the With Project are the upper three locks on the Ohio River (Emsworth, Dashields, and Montgomery, commonly referred to as EDM). As described in Section 4 of this appendix, the EDM projects are unique because their main chamber is only 110' wide x 600' long and the auxiliary chamber is extremely

small, measuring 56' wide by 360' long. Therefore, extensions of the auxiliary chamber at EDM are not practical. The conceptual With Project design and estimates at EDM include new 110' x 600' lock chambers, as well as new 110' x 1200' lock chambers. Individual conceptual designs and costs estimates were developed for each of these projects in order to account for unique site specific conditions.

The details of the engineering plans and how they are implemented in the overall analysis is covered in the Economics Appendix, please refer to it for further clarification as necessary.

7.2 NEWBURGH LOCKS AND DAM LARGE SCALE CAPACITY IMPROVEMENTS

7.2.1 Background on Existing Project - Newburgh

Newburgh Locks and Dam are located at Ohio River mile 776.1 approximately 16 miles upstream of Evansville, Indiana. The project is on the lower Ohio River between the Cannelton and John T. Myers projects. Refer to Figure ED 4-1 for a plan and profile view of the Ohio River. Construction on the Newburgh project occurred between 1966 and 1975. It is a high lift project with twin lock chambers and a gated dam with a short fixed weir. Newburgh has a lift of 16 feet at normal pool levels, which makes it the lowest lift of all the modern Ohio River lock and dam projects. There is a riverside 1200' x 110' main chamber and a landside 600' x 110' auxiliary chamber, typical for most Ohio River projects. A recent aerial photograph of the project is shown in Figure ED 4-43. Newburgh is one of the higher traffic sites on the Ohio River system with approximately 65 million tons transiting through the project annually. In addition, approximately 1,800 recreational craft transit through the facility annually. This makes it the third busiest project on the Ohio River with a 600' auxiliary chamber in terms of annual tonnage (behind Greenup and J.T. Myers). It also makes it the busiest Ohio River project where a capacity improvement is not currently authorized for improvements. For a more detailed description of the existing project features, please refer to Section 4.18 of this Engineering Appendix.

7.2.2 Assessment of Problems and Needs - Newburgh

Currently, the main problem at Newburgh centers on the size of the existing auxiliary chamber relative to the traffic levels at the project. Tow traffic is typically configured to transit through the existing 1200' main chamber in order to maximize shipping efficiency. However, main chamber closures occur for periodic maintenance, inspections, testing, and accidents. When the main chamber is closed, the tows are required to lock through the shorter 600' auxiliary chamber. Since most tows are configured to be longer than 600 feet in length, the barges must be "broken apart" at the project and moved through the shorter auxiliary chamber. This typically requires the use of a helper boat to assist in this process. This is referred to "double-cutting" of tows. Double-cutting drastically increases transit time through the facility. During lengthy closures (over 10 days), a queue of tows builds at the site as processing through the auxiliary chamber slows the entire transit process down. In many instances, tows have to wait several days to lock through the project when the main chamber is closed for major

maintenance work. In contrast, it usually takes about an hour or so to process through the facility (including approach times) when both chambers are open. This problem will only worsen as the project continues to age and experiences more operating cycles on its major components. Therefore, it is evident that capacity improvements at the site are what should be investigated as part of the ORMSS With Project assessments.

7.2.3 Large Scale Improvement Alternatives Considered - Newburgh

Newburgh is almost an exact replica of the next project downstream, John T. Myers. They have the same basic elevations, clearances, and stationing relative to one another. They were both constructed in the same general time frame and are both high-traffic projects, although Newburgh slightly less than J.T. Myers. Therefore, the conceptual large scale improvements evaluated for the Newburgh project relied heavily upon alternatives that were investigated as part of the ORMSS Interim Report, which authorized the auxiliary lock chamber extension at John T. Myers. The J.T. Myers Locks Improvements Project was authorized as part of the Water Resources Development Act (WRDA) of 2000. Thus, the capacity improvement designs and cost estimates for the J.T. Myers project were developed to feasibility level for that project authorization. Since Newburgh is very similar to the J.T. Myers project, conceptual designs and estimates were pulled from the ORMSS Interim Report and site adapted for Newburgh for the purposes of the ORMSS SIP. In addition, recent hydraulic modeling done for the J.T. Myers Locks Improvements Project at ERDC-WES has indicated more cost effective ways to achieve the desired capacity improvements, while potentially lowering the cost of the overall project. These changes were based upon test results from three recently constructed physical hydraulic models: a 1:25 scale filling and emptying (F/E) model, 1:25 outlet diffuser model, and 1:100 navigation model.

The first model constructed was the 1:25 F/E system model that was originally started under the ORMSS project. This model was based upon the J.T. Myers project features. The purpose of the 1:25 F/E model was to investigate more cost effective ways to provide supplemental water for filling and emptying an extended lock chamber as compared to the wrap around culvert system. The design that provided the best balance of potential savings and good performance was a through-the-sill filling system utilizing new slender culverts on the lock floor of the existing auxiliary chamber and tying into the new culvert in the lower land wall. This is combined with a new downstream lateral field and a landside outlet diffuser that empties the lower half of the lock chamber. By utilizing the existing lock chamber floor, the through-the-sill system provides significant savings when compared to the wrap around culvert system. This system does not require removal and replacement of the existing boat mooring facility or the excavation and dewatering required for wrap around culvert. In addition, a deep excavation for an intake structure and an independent culvert valve monolith in the esplanade area are not required with the through-the-sill system. It is estimated that the through-the-sill F/E system will save in the range of 15 million dollars in construction costs when compared to the wrap around culvert system. The performance of the through-the-sill F/E system is also good in terms of filling and emptying times with acceptable hawser forces in the lock chamber. Based upon 1:25 model testing, the filling time is anticipated to be approximately 11-12 minutes for maximum pool differential, while emptying matches that of the existing 1200' chamber at 8-9 minutes. The F/E model was fully tested with the exception of the outlet diffuser which is currently undergoing design refinements.

The second model constructed and tested was the 1:100 navigation model. This model was constructed to evaluate alternative approach wall configurations, as well as test access into and out of both chambers for each alternative. This model has been used to determine the preferred approach wall lengths for the project. This effort has been closely coordinated with the navigation industry and environmental resource agencies, as have the coordination on other models for the J.T. Myers Locks Improvements Project. In addition, the 1:100 model has provided valuable feedback that has led to proposed bank line changes close to the lock to improve tow access into and out of the extended lock chamber. The testing from the 1:100 model has allowed the Louisville District to reduce the overall length of approach walls by 800 feet saving approximately 7 million dollars versus the original authorized plan for J.T. Myers. These same type of savings are anticipated for the Newburgh site as well and thus, have been included as part of the base plan for Newburgh.

The final physical hydraulic model constructed and tested for J.T. Myers was the 1:25 outlet diffuser model. Due to previous arrangements, the original flume used for the ORMSS and J.T. Myers F/E model was turned over by the Louisville District to the Huntington District for their use in modeling the Greenup Lock Extension Project. The only thing that was not completely tested in the J.T. Myers 1:25 F/E model was the outlet diffuser configuration. Therefore, a 1:25 scale model of the outlet diffuser and lower approach was constructed and tested to determine the best configuration of these features. This model is still undergoing testing and the latest changes from the model will be incorporated into both the updated design and cost estimate as the ORMSS progresses. Model testing for the 1:25 outlet diffuser model should be completed prior to the Draft ORMSS Report due near the end of FY04.

All of the changes for the J.T. Myers Locks Improvements Project from recent model tests have been incorporated into the Newburgh base plan for the ORMSS SIP. Any changes that may be made as a result of on-going testing after the submission of this Preliminary Draft ORMSS Report will be incorporated into the Draft ORMSS Report the following year. Since various capacity improvement alternatives would be evaluated in follow-on studies, a broader range of plans are also being evaluated for Newburgh as part of the ORMSS SIP. This includes both a lower cost option and higher cost option when compared to the base plan. The differences between these plans and the base plans are also provided within this narrative. A summary of the full range of plans considered for the ORMSS SIP is provided below.

Base Plan - Same Basic Features as J.T. Myers Locks Improvements Project. This plan for capacity enhancements at Newburgh has all the same basic features that are currently included as part of the J.T. Myers Locks Improvements Project. This basically includes an extension of the existing auxiliary chamber to a nominal 1200' length, new lower land and lower middle approach walls, extensions of the upper river and middle approach walls, supplemental filling and emptying system to provide water to the new lower area of the extended lock chamber, new miter gates and storage pier, as well as aquatic mitigation features. Because Newburgh is so similar to J.T. Myers, this base plan for Newburgh also incorporates the most recent design changes to the J.T. Myers Locks Improvements Project as a result of physical hydraulic modeling at ERDC-WES. A plan view of the base plan capacity enhancement features for Newburgh is provided in Figure ED 7-1. The separate features of the base plan are broken down below into four main categories with new features shaded red in Figure ED 7-1.

1. Extension of the Auxiliary Chamber
   - New lower float-in land wall to form lock chamber extension
   - New lower float-in miter gate bay monolith
   - New miter gates for lower end of extended lock chamber
2. Supplemental Filling and Emptying System
   - New intake upstream of existing upper miter gate sill
   - New twin, triple box culverts on existing aux. chamber floor
   - New downstream lateral field for flow distribution
   - New filling and emptying culvert valves
   - New landward outlet diffuser
3. Approaches
   - New floating extension of existing upper riverward approach wall
   - New floating extension of existing upper middle approach wall
   - New lower middle approach wall
   - New lower landward approach wall
   - Modified upstream bank line for improved access for land chamber
4. Other
   - Aquatic mitigation features
   - Resident engineer office / operations support facility
   - Removal and rehabilitation of existing miter gates (spare set)
   - New on-site miter gate storage pier

The estimated cost for the base plan is approximately $140 million in October 2003 price levels compared to the J.T. Myers authorized cost of approximately $185 million. The principal savings in the Newburgh Base Plan are associated with shortened approach wall lengths, a new through-the-sill supplemental F/E system, and elimination of the construction of a new dry dock facility. A summary of major cost items and quantities is provided in Table ED 7-1. The same unit costs that were used for the authorization of the J.T. Myers Locks Improvements Project were used in the estimate for the Newburgh capacity improvement plans. However, the unit cost estimates were updated to reflect current pricing levels.

Lower Cost Capacity Improvements - Limited Version of Base Plan. The lower cost option for capacity improvement at Newburgh is intended to represent a reasonable lower bound with respect to improvement options and costs. It uses the base plan as a starting point and strips out select features and modifies others in order to still provide twin 1200-ft lock chambers but with fewer features than the base plan. The same type of construction procedures used for the base plan are also assumed for the lower cost option with the exception of the land wall extension which will use a lower cost method. The lower cost plan includes an extension of the existing auxiliary chamber to a nominal 1200' length, new lower land approach wall, extensions of the upper river and middle approach walls, and aquatic mitigation features.

The stripped out features from the base plan include no supplemental filling/emptying system, no miter gate storage pier, use of the existing lower auxiliary chamber miter gates for the newly extended lock chamber as opposed to new miter gates. No diffuser is necessary since there is no supplemental filling/emptying system. Also, since the lower middle approach wall is not required for navigation conditions at J.T.

Myers based upon hydraulic modeling and is used strictly for protection of the miter gates, it is also eliminated as part of the lower cost option at Newburgh. Finally, minimal lengths of approach wall extension on the upper end are assumed. The minimal length assumed is based upon a navigation rule-of-thumb of 600 feet clear between the end of the upper land guide wall and end of the upper middle wall extension. This same relationship is assumed between the upper middle wall approach wall extension and upper river guard wall extension. The lower land wall will be shortened by 100 feet since that was adequate from a modeling standpoint for J.T. Myers. The additional lengths were added for J.T. Myers due to specific outdraft issues at that project. Bank line improvements are assumed not to be required as part of the lower cost option since this was site specific to J.T. Myers and have also been eliminated from the design and cost estimate for the lower cost option at Newburgh. Costs are further reduced for design and construction management since many features will utilize the same as those designed for J.T. Myers. Construction management costs are lowered because there is less construction required with the low cost option.

Newburgh Auxiliary Lock Extension
Base Plan Cost Estimate

Applicable Changes from J.T. Myers Estimate

	J.T. Myers Lock Extension	Newburgh Lock Extension		
Major Feature	Authorized Feature Cost	Updated Feature Cost	Change	Reason for Change
Lands and Damages	$50,000	$50,000	$0	No change from authorized project
Mobilization and Demobilization	$3,655,000	$3,655,000	$0	No change from authorized project
Care and Diversion of Water	$537,000	$537,000	$0	No change from authorized project
Permanent Access Roads & Parking	$975,000	$36,000	$939,000	Changes to new F/E system do not require esplanade changes or revised parking areas
Buildings, Project Operations	$174,000	$1,000,000	-$826,000	New RE Office & truck maintenance building added to project
Earthwork and Foundations for Structures	$10,647,000	$10,647,000	$0	No change from authorized project
Lock Gates and Machinery	$4,922,000	$6,922,000	-$2,000,000	Miter gate storage pier added to project
Approach Walls Including Piers	$38,964,000	$31,689,000	$7,275,000	Walls shortened based upon 1:100 physical hydraulic modeling @ ERDC-WES
Lock Structure	$32,173,000	$30,802,000	$2,371,000	Existing monolith anchoring not required at Newburgh Project
Supplemental F/E System	$28,113,000	$12,500,000	$15,613,000	New through-the-sill supplemental F/E system eliminates need for costly wrap around and dewatering system
Piping System	$687,000	$687,000	$0	No change from authorized project
Power and Lighting System	$2,231,000	$2,231,000	$0	No change from authorized project
Dry Dock for Off Site Construction	$4,602,000	$500,000	$4,102,000	Assumes government owned dry dock facility available by time Newburgh. Minimal costs to facility site as necessary.
Construction Moorage & Service Roads	$2,229,000	$2,229,000	$0	No change from authorized project
Fish and Wildlife Facilities	$4,600,000	$4,600,000	$0	No change from authorized project
Relocate Existing Boat Mooring Area	$3,752,000	$0	$3,752,000	New through-the-sill supplemental F/E system eliminates need to relocate boat mooring facility
Downstream Approach Excavation	$3,677,000	$735,000	$2,942,000	1:100 hydraulic modeling at WES showed very limited need for lower approach excavation
Other Miscellaneous Sitework	$733,000	$733,000	$0	No change from authorized project
PED and Construction Management	$29,453,000	$21,658,628	$7,794,372	Many design, modeling and other savings will be reaped by utilizing same design as J.T. Myers for major project features
EM 1304 Cost Index (Oct 1999 to Oct 2003)	1.0674	1.0674	1.0674	
PROJECT TOTALS	$184,845,928	$140,055,292	$44,790,636	

Table ED 7-1. Newburgh Base Plan Cost Table vs. Authorized Plan

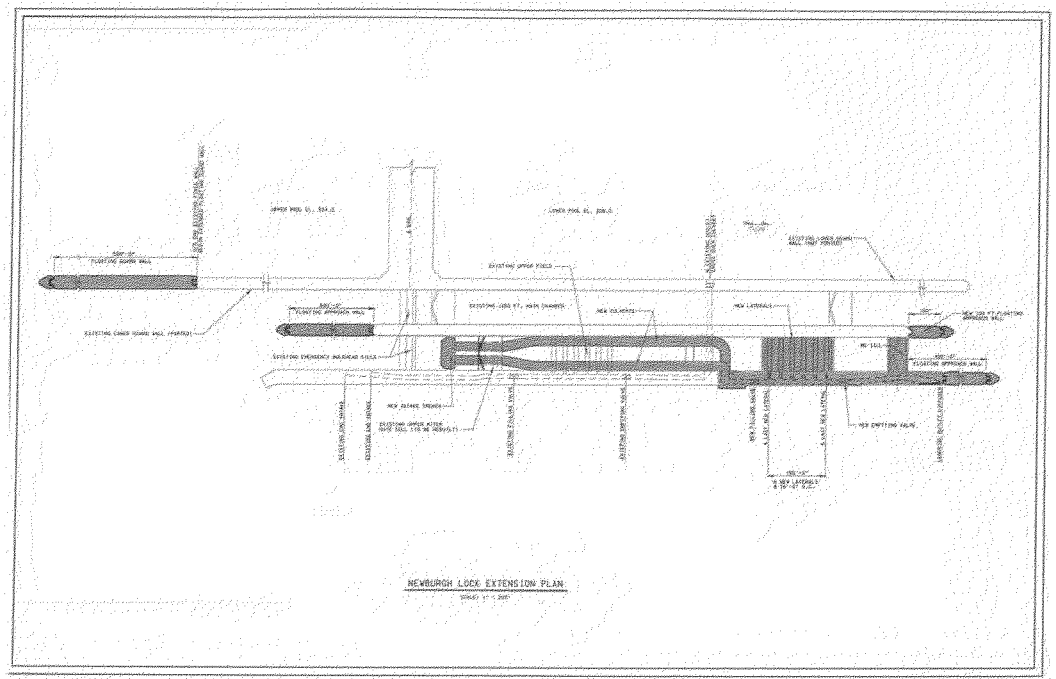


Figure ED 7-1. Newburgh Lock Extension Plan View – Base Plan

The service level associated with the lower cost option will be somewhat reduced from that provided in the base plan. For example, filling time for the lower cost extended lock chamber will be approximately 20-25 minutes compared to 11-12 minutes in the base plan with the supplemental filling/emptying system. Emptying time will also be approximately 20 minutes compared to 8 minutes with the supplemental system. This information is based upon testing of the extended chamber at J.T. Myers with only the existing 600-ft chamber features. In addition, there is another drawback associated with using only the existing 600-ft lock chamber features to fill and empty the extended chamber besides just a slower fill and empty times. The maintenance or failure of the existing valves will require a complete chamber shutdown, whereas, the base plan includes four sets of valves that can be isolated for repairs such that slower chamber operation can continue in the event of valve maintenance or failure.

The conceptual cost estimate for the lower cost alternative is approximately $105 million with basic details shown in Table ED 7-2, which compares it to the low cost alternative. The majority of the savings compared to the base plan come from the elimination of the supplemental filling system, utilization of the existing miter gates on the lower end of the extended chamber, eliminating the on-site miter gate storage pier, and reducing the approach wall lengths.

Newburgh Auxiliary Lock Extension
Low Cost Option

Applicable Changes from Newburgh Base Plan

	BASE PLAN	*LOW COST PLAN*		
	Newburgh Lock Extension	Newburgh Lock Extension		
Major Feature	Updated Feature Cost	Updated Feature Cost	Change	Reason for Change from BASE Plan
Lands and Damages	$50,000	$50,000	$0	No change from BASE plan
Mobilization and Demobilization	$3,655,000	$3,655,000	$0	No change from BASE plan
Care and Diversion of Water	$537,000	$537,000	$0	No change from BASE plan
Permanent Access Roads & Parking	$36,000	$36,000	$0	No change from BASE plan
Buildings, Project Operations	$1,000,000	$1,000,000	$0	No change from BASE plan
Earthwork and Foundations for Structures	$10,647,000	$10,647,000	$0	No change from BASE plan
Lock Gates and Machinery	$6,922,000	$1,417,000	$5,505,000	Use existing lower auxiliary gates, no pier
Approach Walls Including Piers	$31,689,000	$22,235,000	$9,454,000	Wall lengths reduced by additional 600 feet. Eliminate another pier and pylon for LMW.
Lock Structure	$30,802,000	$30,802,000	$0	No change from BASE plan
Supplemental F/E System	$12,500,000	$0	$12,500,000	No supplemental F/E system provided for low cost option. Slower fill and empty time.
Piping System	$687,000	$687,000	$0	No change from BASE plan
Power and Lighting System	$2,231,000	$2,231,000	$0	No change from BASE plan
Dry Dock for Off Site Construction	$500,000	$500,000	$0	No change from BASE plan
Construction Moorage & Service Roads	$2,229,000	$2,229,000	$0	No change from BASE plan
Fish and Wildlife Facilities	$4,600,000	$4,600,000	$0	No change from BASE plan
Relocate Existing Boat Mooring Area	$0	$0	$0	No change from BASE plan
Downstream Approach Excavation	$735,000	$735,000	$0	No change from BASE plan
Other Miscellaneous Sitework	$733,000	$733,000	$0	No change from BASE plan
PED and Construction Management	$21,658,628	$16,229,984	$5,428,644	Less features to design than BASE plan, thus, less costly engineering and construction management costs anticipated
EM 1304 Cost Indext (Oct 1999 to Oct 2003)	1.0674	1.0674	1.0674	
PROJECT TOTALS	**$140,055,292**	**$104,951,020**	**$35,104,272**	

Table ED 7-2. Newburgh Low Cost Alternative Estimate vs. Base Plan

Higher Cost Option for Capacity Improvements - Based Upon Authorized Project Features at J.T. Myers. For the purposes of the ORMSS SIP, the authorized cost of approximately $184 million (October 2003 price levels) will be used as the high cost alternative. An overall description of the major project features is provided in Section 4.19.4 of this Engineering Appendix. A plan view of the project features associated with the authorized project is shown in Figure ED 4-47.

7.3 MELDAHL LOCKS AND DAM LARGE SCALE CAPACITY IMPROVEMENTS

7.3.1 Background on Existing Project - Meldahl

Meldahl Locks and Dam are located at Ohio River mile 436.2 approximately 1.7 miles downstream of Chilo, Ohio. The navigation locks are located on the North bank, or the Ohio side. The pool extends from the dam upstream for a distance of 95.2 miles to Greenup Dam, located at river mile 341.0. Refer to Figure ED 4-1 for a plan and profile view of the Ohio River. Construction on the Meldahl project occurred between 1959 and 1965. It is a high lift project with twin lock chambers and a gated dam with a short fixed weir. Meldahl has a lift of 30 feet at normal pool levels. There is a riverside 1200' x 110' main chamber and a landside 600' x 110' auxiliary chamber, typical for most Ohio River projects. A recent aerial photograph of the project is shown in Figure ED 4-32. Meldahl is one of the higher traffic sites on the Ohio River system. For a more detailed description of the existing project features, please refer to Section 4.14 of this appendix.

7.3.2 Assessment of Problems and Needs - Meldahl

Currently, the main problem at Meldahl centers on the size of the existing auxiliary chamber relative to the traffic levels at the project coupled with the future reliability of major lock components associated with the main lock chamber. Tow traffic is typically configured to transit through the existing 1200' main chamber in order to maximize shipping efficiency. However, main chamber closures occur for periodic maintenance, inspections, testing, and accidents. This situation is similar to the issue as described in Section 7.1, which covers that same issue for problems and needs at Newburgh. Please refer to that section for a complete description.

7.3.3 Large Scale Improvement Alternatives Considered - Meldahl

Meldahl is similar to several auxiliary lock chamber extension projects being evaluated along the Ohio River as part of this ORMSS SIP study. These nominal 600-foot extension projects all have the same basic features that include extending the land wall on the lower end, providing additional approach wall lengths, and evaluating supplemental F/E systems for the auxiliary lock being extended. Therefore, the conceptual large scale improvements evaluated for the Meldahl project relied heavily upon alternatives that were investigated as part of the ORMSS Interim Report, which authorized the auxiliary lock chamber extensions at John T. Myers and Greenup. As noted earlier, the J.T. Myers and Greenup Locks Improvements Projects were authorized as part of the WRDA of 2000. Thus, the capacity improvement designs and cost estimates for the J.T. Myers and the Greenup projects were developed to feasibility level for these project authorizations. Since Meldahl is very similar to the J.T. Myers and the Greenup projects, conceptual designs and estimates were pulled from the ORMSS Interim Report and site adapted for Meldahl for the purposes of the ORMSS SIP. In addition, recent hydraulic modeling done for the J.T. Myers and Greenup Locks Improvements Project at ERDC-WES has indicated more cost effective ways to provide many of these same features at a lower cost. Many of these features are also applicable for lock extension option at Meldahl and have been included where feasible.

The first models constructed were the two 1:25 F/E system models that were originally started under the ORMSS project. These models were based upon the features of the J.T. Myers and Greenup projects. The purpose of the 1:25 F/E models was to investigate more cost effective ways to provide supplemental water for filling and emptying an extended lock chamber as compared to the wrap around culvert system. As noted earlier in the Newburgh narrative, the design that provided the best balance of potential savings and good performance was a through-the-sill filling system utilizing new slender culverts on the lock floor of the existing auxiliary chamber and tying into the new culvert in the lower land wall. This is combined with a new downstream lateral field and a landside outlet diffuser that empties the lower half of the lock chamber. By utilizing the existing lock chamber floor, the through-the-sill system provides significant savings when compared to the wrap around culvert system. However, due to unique project conditions at the Greenup and Meldahl locks and dam, the through-the-sill filling and emptying system was determined to be not feasible due to clearance issues. For this reason, Meldahl currently intends use a wrap around culvert system for the supplemental F/E system. The testing of the wrap around culvert model for Greenup is started and scheduled to be completed in FY 04. Although this is more expensive, it is still an acceptable method for filling and emptying. The performance of the wrap around culvert F/E system is good in terms of filling and emptying times with acceptable hawser forces in the lock chamber. Based upon numerical modeling, the filling time is anticipated to be approximately 9 minutes for maximum pool differential, while emptying matches that of the existing 1200' chamber at 9 minutes. The F/E model was fully tested with the exception of the outlet diffuser which will use information gathered from the 1:25 J.T. Myers models for design considerations.

The second type of model constructed and tested were the 1:100 navigation models. One was built for the J.T. Myers Project and one was built for the Greenup Project. These models were constructed to evaluate alternative approach wall configurations, as well as to test access into and out of both chambers for each alternative. The models have been used to determine the preferred approach wall lengths for the project. This effort has been closely coordinated with the navigation industry and environmental resource agencies, as have the coordination on other models for the 600 foot lock extension improvement projects. In addition, the 1:100 models have provided valuable feedback that has led to proposed bank line changes close to the lock to improve tow access into and out of the extended lock chamber.

The final physical hydraulic model was constructed and tested for J.T. Myers. This was the 1:25 outlet diffuser model. Due to previous arrangements, the original flume used for the ORMSS and J.T. Myers F/E model was turned over by the Louisville District to the Huntington District for their use in modeling the Greenup Lock Extension Project. The only thing that was not completely tested in the J.T. Myers 1:25 F/E model was the outlet diffuser configuration. Therefore, a 1:25 scale model of the outlet diffuser and lower approach was constructed and tested to determine the best configuration of these features. This model is still undergoing testing and the latest changes from the model will be incorporated into both the updated design and cost estimate.

Some of these changes for the 600 foot lock extension improvement projects from recent model tests have been incorporated into the Meldahl base plan for the ORMSS SIP. Since various capacity improvement alternatives would be evaluated in follow-on studies, a broader range of plans are also being evaluated for Meldahl as part of the ORMSS SIP. This includes both a lower cost option and higher cost option when

compared to the base plan. The differences between these plans and the base plans are also provided within this narrative. A summary of the full range of plans considered for the ORMSS SIP is provided below.

Base Plan - Same Basic Features as Greenup Locks Improvements Project. This plan for capacity enhancements at Meldahl has all the same basic features that are currently included as part of the authorized Greenup Lock Extension Project. This basically includes an extension of the existing auxiliary chamber to a nominal 1200' length, new lower land walls, extensions of the upper river and middle approach walls, supplemental filling and emptying system to provide water to the new lower area of the extended lock chamber, new miter gates and storage pier, as well as aquatic mitigation features. Because Meldahl is so similar to J.T. Myers and Greenup, this base plan for Meldahl also incorporates applicable recent design changes to the 600 foot lock extension improvement projects as a result of physical hydraulic modeling at ERDC-WES. The separate features of the base plan are broken down below into four main categories.

1. Extension of the Auxiliary Chamber
   - New lower lift-in land wall to form lock chamber extension
   - New lower float-in miter gate bay monolith
   - New miter gates for lower end of extended lock chamber
2. Supplemental Filling and Emptying System
   - Wrap around filling system
   - New downstream lateral field for flow distribution
   - New filling and emptying culvert valves
   - New outlet diffuser
3. Approaches
   - New floating extension of existing upper riverward approach wall
   - New floating extension of existing upper middle approach wall
   - New lower landward approach wall
4. Other
   - Aquatic mitigation features
   - Resident engineer office / operations support facility
   - New on-site miter gate storage pier

The estimated cost for the base plan is approximately $162 million dollars compared to the authorized cost of approximately $187 million. The major portion of the $25 million dollar savings associated with the Base Plan at Meldahl is for the shortening of approach wall length extensions to match those determined to be adequate out of the 1:100 J.T. Myers hydraulic model. A summary of major cost items and quantities is provided in Table ED 7-3. The same unit costs that were used for the authorization of the Greenup Improvements Project were used in the estimate for the Meldahl capacity improvement plans. Quantities were updated where applicable. The overall cost was inflated to match current pricing levels by using USACE Engineering Manual 1110-2-1304, which accounts for inflation factors for civil works construction within USACE.

Meldahl Auxiliary Lock Extension
Base Plan Cost Estimate

Applicable Changes from Greenup Locks
Improvements Project

Major Feature	Greenup Lock Extension Project Authorized Feature Cost	Meldahl Lock Extension Updated Feature Cost	Change	Reason for Change
Relocations	$600,000	$600,000	$0	No change from authorized project
Mobilization and Demobilization	$1,032,000	$1,032,000	$0	No change from authorized project
Drainage and Care/Diversion of Water	$767,400	$767,400	$0	No change from authorized project
Permanent/Temporary Roads and Access	$222,800	$222,800	$0	No change from authorized project
Resident Engineer's Office	$463,100	$463,100	$0	No change from authorized project
Utilities, Lines, and Services	$950,600	$950,600	$0	No change from authorized project
Earthwork and Foundations for Structures	$284,700	$284,700	$0	No change from authorized project
Lock Gates, Assembly Pier, and Machinery	$6,956,600	$6,956,600	$0	No change from authorized project
Approach Walls Including Piers	$50,568,700	$34,871,700	$15,697,000	Pontoon walls shortened to lengths from 1:100 navigation model at J.T. Myers
Lock Structure	$30,418,600	$30,418,600	$0	No change from authorized project
Supplemental F/E System	$22,393,700	$22,393,700	$0	No change from authorized project
Lock Wall Demolition	$3,498,200	$3,498,200	$0	No change from authorized project
Piping System	$402,100	$402,100	$0	No change from authorized project
Power and Lighting System	$3,860,000	$3,860,000	$0	No change from authorized project
Associated General Items (Dry Dock Facility, Lock Equipment, Vehicles, Demo Projects, Etc...)	$16,911,400	$12,744,300	$4,167,100	Assume existing casting facility available with minimal (500k) retrofit needed. Also, eliminate one demonstration project on construction methods
Fish and Wildlife Facilities	$5,634,900	$5,634,900	$0	No change from authorized project
Water Lines	$20,000	$20,000	$0	No change from authorized project
Fencing	$83,500	$83,500	$0	No change from authorized project
Parking Lots	$545,000	$545,000	$0	No change from authorized project
Picnic Shelter and Day Use Area	$133,000	$133,000	$0	No change from authorized project
PED and Construction Management	$29,843,550	$25,753,436	$4,090,114	Many design, modeling and other savings will be reaped by utilizing same design as Greenup and J.T. Myers for major project features
EM 1304 Cost Index (Oct 1999 to Oct 2003)	1.0674	1.0674	1.0674	
PROJECT TOTALS	$187,424,606	$161,855,878	$25,568,728	

Table ED 7-3. Meldahl Base Plan Cost Estimate vs. Authorized Greenup Estimate

Lower Cost Capacity Improvements - Limited Version of Base Plan. The lower cost option for capacity improvement at Meldahl is intended to represent a reasonable lower bound with respect to improvement options and costs. It uses the base plan as a starting point and strips out select features in order to still provide twin 1200-ft lock chambers but with fewer features than the base plan. The same type of construction procedures used for the Base Plan are also used in the lower cost option. The lower cost option includes an extension of the existing auxiliary chamber to a nominal 1200' length, new lower land approach wall, extensions of the upper river and middle approach walls, plus aquatic mitigation features.

The primary stripped out feature in the Low Cost Plan from the Base Plan is the removal of the supplemental F/E system. The condition of the existing main chamber miter gates warrants new miter gates and the inclusion of a storage/construction pier. In addition, minimal lengths of approach wall extension on the upper end are assumed.

The service level associated with the lower cost option will be somewhat reduced from that provided in the base plan. For example, filling time for the lower cost extended lock chamber will be approximately 20 minutes compared to 9 minutes in the base plan. This information is based upon computer modeling for Meldahl with only the existing 600-ft chamber features. Emptying time should also be near 20 minutes compared to 9 minutes for an existing 1200-ft main chamber. Additionally, maintenance or failure of the existing valves will require a complete chamber shutdown, whereas, the base plan includes four sets of valves such that slower chamber operation can continue in the event of valve maintenance or failure.

The lower cost option is estimated to be approximately $133 million. This cost is essentially determined by taking the supplemental F/E system out of the Base Plan cost estimate.

Higher Cost Option for Capacity Improvements - Based Upon Authorized Project Features at Greenup. For the purposes of the ORMSS SIP, the authorized cost of approximately $187 million (October 2003 price levels) will be used as the high cost alternative. An overall description of the major project features has been noted previously throughout this appendix.

7.4 EMSWORTH LOCKS AND DAM LARGE SCALE CAPACITY IMPROVEMENTS

7.4.1 Background on Existing Project - Emsworth

Emsworth Locks and Dam are located at Ohio River mile 6.2 approximately six miles downstream of Pittsburgh, Pennsylvania. The project is the first Lock and Dam on the Ohio River. Refer to Figure ED 4-1 for a plan and profile view of the Ohio River. Construction on the original Emsworth project occurred between 1919 and 1922, followed by a reconstruction of the fixed-crest dams on the main channel and back channels of the Ohio River, to transform them into gated structures in 1937. It is a low lift project with twin lock chambers and gated dams on both the main channel and back channel, with a short fixed weir on the main channel. Emsworth has a lift of 18 feet at normal pool levels. There is a riverside 600' x 110' main chamber and a landside 360' x 56' auxiliary chamber, quite atypical for most Ohio River projects, which have a 1200' x 110' main chamber with a 600' x 110' auxiliary chamber. A recent aerial photograph of the project is shown in Figure ED 4-3. Emsworth Locks and Dams project is the oldest facility on the entire Ohio River, although many parts were upgraded as part of a major rehabilitation program on the upper three Ohio River projects (Emsworth, Dashields, and Montgomery) during the mid-to-late 1980's. Significant problems remain with existing features (mass concrete, etc...) that were unable to be upgraded during the major rehabilitation. In addition, closures of the main chamber forces traffic to divert to the small 56' x 300' auxiliary, which result in significant delay cost to the navigation industry. For a more detailed description of the existing project features, please refer to Section 4.3 of this appendix.

7.4.2 Assessment of Problems and Needs - Emsworth

The Emsworth project plays a major role in the economy of the Pittsburgh region, since the Emsworth dams create and control the pool which flows adjacent to the city of Pittsburgh and its adjoining communities. One major issue associated with the project is the structural deficiencies of the dam associated with both the machinery and vertical lift gates that limits its capacity to control pool elevations under extreme flow conditions. The project is situated in a highly industrialized area with many of the industrial plants relying heavily on water transportation for the receiving of raw materials and the shipping of finished products. Should the lift gates of the dam and/or lifting machinery fail, the resulting loss of pool would be catastrophic with the above mentioned industrial complex's dependence on water transportation. In addition, power plants and industrial and municipal water intakes which rely on water transportation and relatively stable pools would be adversely affected. Two of the 14 dam gates have become inoperable due to reported deficiencies. One of these gates and machinery (gate bay No. 6) was replaced in

2002. A major rehabilitation report for the dam at Emsworth was approved at HQUSACE in 2002, however, funds have not yet been procured to upgrade the dam at Emsworth.

The other primary issue associated with the condition of the Emsworth project is the condition of the mass concrete at the locks. The concrete is already in a poor condition. The main cause of concrete deterioration for the locks and dams is from weathering due to freeze-thaw activity. Due to the fact that the locks and dams were constructed prior to the advent of air-entrained concrete, the mass structure has been particularly susceptible to weathering and freeze-thaw damage. Prior to the major rehabilitation effort in the mid-1980s, horizontal and vertical surfaces of the lock walls were in advanced stages of deterioration. At Emsworth, the vertical and horizontal extent of concrete deterioration measured from the top and chamber face of the lock walls was up to 4.5 and 1.5 feet, respectively. The major rehabilitation projects detailed varying levels of horizontal and vertical wall repairs. As stated previously, these repairs were performed in order to extend the useful life of the projects for another 25 years. These horizontal concrete overlays and vertical refacing of the lock chamber walls are considered cosmetic in nature and do not address the underlying problems associated with the deteriorated state of the existing mass concrete. A more detailed description of the concerns and needs associated with the Emsworth project, including a broad overview of the major rehabilitation that was done during the 1980s, is provided in Section 4.3 of this appendix.

7.4.3 Large Scale Improvement Alternatives Considered - Emsworth

There are four basic With Project plans that are being evaluated as part of project improvements at Emsworth Locks and Dam. All of these With Project plans at Emsworth call for a minimum of one new lock chamber to replace the existing, small auxiliary lock chamber. An auxiliary chamber lock extension at Emsworth, such as those evaluated at Newburgh and Meldahl, is not a practical alternative due to the fact that the existing auxiliary lock chamber is only 56-ft wide. In addition, the mass concrete of the auxiliary lock chamber is in a deteriorated condition and its long-term reliability will be poor without proactive measures. Therefore, an array of new riverward locks are being evaluated to determine their economic merit when compared to the optimized Without Project Condition. Lengths of this proposed new riverward chamber vary. Both 1200-ft long and 600-ft long riverward chambers are being evaluated to determine their economic merit.

For each of these With Project plans, it is anticipated that innovative in-the-wet construction techniques will be utilized in order to reduce construction costs and limit navigation traffic disruptions. Similar construction techniques as utilized in the J.T. Myers Locks Improvements Project are envisioned for constructing the new larger river chamber. The construction methodology will be considered in detail during any follow-on studies. Conceptual design work done during ORMSS indicates that float-in technology is appealing in terms of reduced construction costs and limited navigation interference. Initial stage lock construction would likely entail the off-site fabrication/casting of base rafts for major concrete construction. The prefabricated monoliths would then be transported to the site, likely by floating the monolith base rafts to the vicinity for continued work on them prior to set down. Once operational, the new riverward chamber would handle the majority of all commercial traffic. Depending upon

the plan being evaluated, the existing main chamber would either be delegated as the auxiliary chamber (Base Plan and Low Cost Plan) or replaced with a new lock chamber (High Cost Plans). In addition, follow-on studies could recommend some type of rehabilitation of the existing main chamber if that remains as the auxiliary chamber.

The proposed new river wall for the new main chamber would be constructed immediately adjacent to Pier No. 2. This riverward movement of the new main chamber is necessary since the proposed twin locks would now be two 110' chambers, whereas the existing locks measure only 110' and 56'. Removal of the short fixed crest weir, adjacent to the river wall provided insufficient lateral space for new chamber construction. Hence, removal of Gate Bay No. 1 becomes necessary. The proposed new middle wall, for the new riverward chamber, would be positioned within the existing 56' auxiliary chamber. This alignment is dictated by geometric requirements (new 110' chamber replacing a 56' chamber, and proposed widths of new river and middle walls. The Emsworth main channel dam will be affected, adversely, by this lock construction. One gate bay (No. 1) is slated for removal to provide lateral space requirements (an active railroad exists along the landward side of the esplanade). Few options exist to gain sufficient space for the new lock widths. Relocation of the railroad, landward, is difficult and costly, due to the hilly terrain and real estate concerns. Riverward movement of the twin locks would be constructible; however, the dam would now be constrained to pass the flows, with only seven gate bays in lieu of eight. Investigations have revealed that options exist for replenishing lost hydraulic capacity of the dam gates. The dam sills could be lowered; however, a significant lowering of several feet would be required. A new gate bay could be constructed on the Neville Island end of the dam. This would have been a viable option prior to commercial development on Neville Island. Now, a modern RPS (commercial freight shipping company) has been constructed immediately landward of the bulkhead storage pit, at the far end of the dam. Another option, prior to RPS construction, was to reroute a portion of the river flow, around the far end of the dam, essentially building a large tunnel, capable of passing flow commensurate with a gate bay. Construction of a floodway was also investigated. The floodway could be installed on the proposed new chamber, to pass the higher (flood) flows, when the miter gates would be inoperable anyway, and locked in place in the recesses. Based on preliminary, concept level cost estimates, construction of the lock chamber floodway appears to be the least cost and has been incorporated into all With Project alternatives. All With Project plans at Emsworth essentially call for the same features and utilized the same construction techniques. The basic difference is the configuration of the new lock(s) in terms of how many and their length. A basic description of each plan is provided below and summarized in Table ED 7-4.

The Base Plan calls for a new riverward 110' x 1200' lock chamber to replace the existing 56-ft wide auxiliary lock chamber. The existing 110' x 600' main chamber would be delegated as the future auxiliary chamber under this plan. The approximate cost of the plan is $290 million.

The Low Cost Plan has a new 110' x 600' lock chamber to replace the existing 56-ft wide auxiliary chamber, while the existing 110' x 600' main chamber would be utilized as the future auxiliary chamber. The approximate cost of this plan is $250 million.

High Cost Plan 1 has twin 110' x 600' lock chambers. Like all other plans, these would be sequenced such that navigation traffic is allowed to pass during the majority of all construction activities. The added benefit of this plan is that the long-term viability of

a reliable auxiliary chamber is not in question since the deteriorated existing main chamber is replaced. The conceptual cost of this alternative is estimated at $370 million.

High Cost Plan 2 has a new 110' x 1200' riverward main chamber and the existing, deteriorated main chamber is replaced with a new 110' x 600 auxiliary lock chamber. Again with this option, the long-term reliability of the "auxiliary" chamber is not a concern with two new lock chambers. This plans is estimated at $400 million.

Alternative	Emsworth With Project Alternatives		Total Cost
Number	River Chamber	Land Chamber	Rounded
Low Cost	New Lock 600' x 110'	Existing Land Chamber Becomes Future Auxiliary Chamber	$250,000,000
Base Plan	New Lock 1200' x 110'	Existing Land Chamber Becomes Future Auxiliary Chamber	$290,000,000
High Cost 1	New Lock 600' x 110'	New Lock 600' x 110'	$370,000,000
High Cost 2	New Lock 1200' x 110'	New Lock 600' x 110'	$400,000,000

Table ED 7-5. Emsworth Locks and Dam
(Preliminary Costs of "3 for 3" With Project Plan Alternatives)

7.5 DASHIELDS LOCKS AND DAM LARGE SCALE CAPACITY IMPROVEMENTS

7.5.1 Background on Existing Project - Dashields

Dashields Locks and Dam are located approximately 13.3 miles downstream of Pittsburgh, Pennsylvania, and 7.1 miles downstream of Emsworth Locks and Dams. The project is the second lock and dam on the Ohio River. Refer to Figure ED 4-1 for a plan and profile view of the Ohio River. Construction on the original Dashields project occurred between 1927 and 1929. It is a low lift project with twin lock chambers and a fixed-crest dam. Dashields is the only lock and dam project on the entire 981 miles of the Ohio River constructed and operating with a fixed crest dam across the entire width of river (no gates). Dashields has a lift of 10 feet at normal pool levels. There is a riverside 600' x 110' main chamber and a landside 360' x 56' auxiliary chamber, similar to the lock configuration found at Emsworth. A recent aerial photograph of the project is shown in Figure ED 4-6. The Dashields Locks and Dams project is one of the oldest facilities on the Ohio River. As such, Dashields has numerous condition-related problems that need to be addressed. For a more detailed description of the existing project features, please refer to Section 4.4 of this appendix.

7.5.2 Assessment of Problems and Needs - Dashields

Unstable guide walls coupled with heavily cracked lockwall concrete contribute to serious condition concerns at Dashields. Analysis of upper and lower guide wall stability has confirmed that the walls are unstable. Survey monitoring has revealed movement in both walls. Failure of the guide wall monoliths has the potential to block the approaches to the land chamber and disrupt river traffic. An unscheduled outage of the main chamber would force all traffic, including doubles, to lock thru the auxiliary

chamber, resulting in significant delays, even with the use of helper boats. Concrete cracking is extremely prevalent throughout the monoliths on the land, middle and river walls, and can be easily seen throughout the pipe galleries. Evidence of cracking in the approach walls is shown in Figures ED 4-8 through 4-11 for photographs of concrete deterioration at Dashields.

The main causes of concrete deterioration for the locks and dam at Dashields are the same as those found at Emsworth, which is weathering and freeze-thaw action on non air entrained concrete. Prior to the major rehabilitation projects on the upper three Ohio River projects in the mid-1980s, the concrete at Dashields was by far in the worse condition both from a deterioration standpoint when compared to Emsworth and Montgomery. Dashields utilizes integral filling and emptying culverts and pipe galleries in all three lock walls. These features result in thin-walled sections with numerous reentrant corners, susceptible to stress concentration areas and increased concrete deterioration. These details coupled with the lack of concrete reinforcing, which would be provided in modern structures, encourage conditions susceptible to cracking. Progressive riverward movement of the upper and lower guide walls continue to be monitored. A recent stability report recommended anchoring to retard the riverward movement.

The lock structure continues to be plagued by interior cracking, located at numerous random positions along the monoliths, but prevalent throughout the filling and emptying valve recesses, bulkhead recesses and miter gate machinery recesses. Several structural repairs were performed during the major rehabilitation project. Recently a structural crack has been identified at the downstream land wall culvert valve recess propagating through to the valve bulkhead recess. Due to the age of the underlying original concrete, typical for all three locks and dams, freeze-thaw cycles have caused cracking and deterioration along weather-susceptible surfaces, such as recesses which are covered with aluminum grating. For a more detailed description of the problems and needs at Dashields, please refer to Section 4.4.3 of this appendix.

7.5.3 Large Scale Improvement Alternatives Considered - Dashields

Referring to the With Project alternatives narrative for Emsworth, Section 7.4.3 of the appendix, the same basic alternatives are being evaluated at Dashields. These plans are summarized in Table ED 7-5 for Dashields. Conceptual costs are also provided for these plans within the table, where it is noticed that the project plans at Dashields are lower than those for Emsworth. Much of this difference can be attributed to the differences between the dam configurations between the two projects and associated changes to manage water flow. In addition, there are variations between projects in terms of material quantities, real estate costs, etc. However, the basic configuration of the lock sizes remains unchanged when compared to the alternatives at Emsworth.

Alternative	Dashields With Project Alternatives		Total Cost
Number	River Chamber	Land Chamber	Rounded
Low Cost	New Lock 600' x 110'	Existing Land Chamber Becomes New Auxiliary Chamber	$210,000,000
Base Plan	New Lock 1200' x 110'	Existing Land Chamber Becomes New Auxiliary Chamber	$275,000,000

High Cost 1	New Lock 600' x 110'	New Lock 600' x 110'	$295,000,000
High Cost 2	New Lock 1200' x 110'	New Lock 600' x 110'	$355,000,000

Table ED 7-5. Dashields Locks and Dam
Preliminary Costs of "3 for 3" Plan Alternatives

7.6 MONTGOMERY LOCKS AND DAM LARGE SCALE CAPACITY IMPROVEMENTS

7.6.1 Background on Existing Project - Montgomery

Montgomery Locks and Dam are located at Ohio River Mile 31.7 approximately 18.4 miles downstream of Dashields Locks and Dam. The project is the third lock and dam on the Ohio River. Refer to Figure ED 4-1 for a plan and profile view of the Ohio River. Construction on the original Montgomery project occurred between 1932 and 1936. It is a low lift project with twin lock chambers and a gated dam. The dam was constructed with 10 gated sections and a fixed weir adjacent to the river wall as well as adjacent to the abutment. Montgomery has a lift of 17.5 feet at normal pool levels. There is a riverside 600' x 110' main chamber and a landside 360' x 56' auxiliary chamber, quite atypical for most Ohio River projects, which have a 1200' x 110' main chamber with a 600' x 110' auxiliary chamber. A recent aerial photograph of the project is shown in Figure ED 4-12. Like Emsworth and Dashields, the Montgomery Locks and Dams project is one of the oldest facilities on the Ohio River, built in the early 20th century. As such, Montgomery has numerous condition-related problems that need attention particularly with a small auxiliary lock chamber. Closures of the main chamber forces traffic to divert to the small 56' x 300' auxiliary, which result in significant delays and lost time to the navigation industry. For a more detailed description of the existing project features, please refer to Section 4.5 of this appendix.

7.6.2 Assessment of Problems and Needs - Montgomery

Montgomery Locks and Dams is one of the oldest operating structures in the Pittsburgh District and has several concerns regarding its long-term operation. Heavily cracked lock wall concrete and dam gate hoist problems are among the most severe issues associated with the condition of the Montgomery Project. Concrete cracking is extremely prevalent throughout the monoliths on the land, middle and river walls, and is readily visible throughout the pipe galleries and within recesses (gate, valve, bulkhead, and ladder ways). The construction technique and materials used (non air entrained concrete) at Montgomery are similar in nature to those used at Emsworth and Dashields. Thus, it is experiencing many of the same problems that were described for those projects, particularly associated with the condition of the mass concrete structure. A few examples of the concrete deterioration is shown in Figures ED 4-14 and 4-15 of this appendix.

The gate hoists on the dam are a serious concern at Montgomery. The condition of the chains, and gate position indicators and two drive motors, one on each pier, creates

a serious situation. The dam gate hoist chains tend to kink and are showing other signs of wear and lack of internal lubrication. The gate position indicators are driven by the hoist machinery and do not directly read the position of the gate. If a hoist chain were to kink or foul, the position indicator would not yield an accurate reading. Maintaining a level gate position is critical to safe dam operation. If a dam gate were to become jammed, part of the hoist machinery could fail and drop or jam the gate. The use of two drive motors in lifting the gate can create a large force. Also, a more positive and reliable method of determining the gate position should be evaluated. Until the condition of the dam gate hoist machinery can be ascertained all mote operations of the dam gates should be discontinued.

The maintenance of the control systems is very difficult because many of the parts are obsolete. Also, some of the original manufacturers are no longer in business, and the parts are not in inventory. Some of the control units were unique designs that were specified by Corps design. In particular, the programmable units are very difficult – if not impossible – to maintain and repair.

For a more detailed description of the assessment of problems and needs for the current project, please refer to Section 4.5.3 of the appendix.

7.6.3 Large Scale Improvement Alternatives Considered - Montgomery

Referring to the With Project alternatives narrative for Emsworth and Dashields, Sections 7.4.3 and 7.5.3 of this appendix, respectively, the same basic alternatives are being evaluated at Montgomery. These plans are summarized in Table ED 7-6 for Montgomery. Site-specific adaptations were made for appropriate features, thus, the conceptual costs vary at Montgomery when compared to Emsworth and Dashields. However, the basic configuration of the lock sizes remains unchanged when compared to the alternatives at Emsworth and Dashields.

Alternative	Montgomery With Project Alternatives		Total Cost
Number	River Chamber	Land Chamber	Rounded
Low Cost	New Lock 600' x 110'	Existing Land Chamber Becomes New Auxiliary Chamber	$240,000,000
Base Plan	New Lock 1200' x 110'	Existing Land Chamber Becomes New Auxiliary Chamber	$325,000,000
High Cost 1	New Lock 600' x 110'	New Lock 600' x 110'	$365,000,000
High Cost 2	New Lock 1200' x 110'	New Lock 600' x 110'	$440,000,000

Table ED 7-6. Montgomery Locks and Dam Preliminary Costs of "3 for 3" Plan Alternatives

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
P.O. BOX 59
LOUISVILLE, KENTUCKY 40201-0059

System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Economics Appendix

July 2011

ORMSS SIP Economics Appendix
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List of Acronyms

ATC	Average Towing Cost
BEA	Bureau of Economic Analysis
BTU	British Thermal Unit
CAAA	Clean Air Act Amendments
COE	Corps of Engineers
CR	Component Replacement
DOE	Department of Energy
EDM	Emsworth, Dashields and Montgomery
EIA	Energy Information Administration
EQ	Equilibrium Model
ER	Engineering Regulation
HQ	Headquarters (Corps)
IWR	Institute for Water Resources
L/D	Lock(s) and Dam
LPMS	Lock Performance Monitoring System
LRD	Great Lakes and Ohio River Division
LRM	Lock Risk Module
MRS	Marginal Rate Savings
MTC	Marginal Towing Cost
NAAQS	National Ambient Air Quality Standards
NAVPAT	Navigation Predictive Analysis Technique
NED	National Economic Development
NER	National Ecosystem Restoration
ODC	Origin-Destination-Commodity
O&M	Operation and Maintenance
OM	Optimization Module
ORB	Ohio River Basin
ORMSS	Ohio River Mainstem Systems Study
ORNIM	Ohio River Navigation Investment Model
ORNL	Oak Ridge National Laboratory
ORS	Ohio River System
P&G	Principles and Guidelines
PMP	Project Management Plan
PRB	Powder River Basin
RM	Reactive Maintenance
SIP	System Investment Plan
TCM	Tow Cost Model
TVA	Tennessee Valley Authority
USACE	US Army Corps of Engineers
WAM	Waterway Analysis Model
WCSC	Waterborne Commerce Statistical Center
WOPC	Without-Project Condition
WPC	With-Project Condition
WSDM	Waterway Supply Demand Module

SECTION 1
INTRODUCTION

1.1 PURPOSE

This document supports the draft Main Report to the Ohio River Mainstem Systems Study (ORMSS) System Investment Plan (SIP). The study will develop the models and databases necessary to evaluate long-range operations, maintenance, and capacity needs; forecast future use and adequacy; and identify long-term maintenance, major rehabilitation and new construction needs for the Ohio River mainstem. It is a feasibility level study that will produce a System Investment Plan (SIP), which will include an array of operational, repair, rehabilitation, and replacement opportunities through 2070 given different traffic demand forecast scenarios.

This Economics Appendix supplements earlier investigations of navigation problems on the Ohio River that indicated a need for larger auxiliary locks at the Myers and Greenup projects. The findings of the Myers/Greenup Interim Report (2001) were to extend the existing auxiliary chambers while conserving fish and wildlife resources.

The purpose of this appendix is to explain the economic foundations and analytic procedures used to estimate the system impacts and the National Economic Development (NED) benefits of an array of navigation improvement investment opportunities identified in the SIP. This study will not recommend a course of action nor will it recommend projects for Congressional authorization. It is intended to recommend more detailed (project level) feasibility studies that could lead to specific authorizations.

The primary benefit for Federal investment in commercially navigable waterways is the collective transportation cost savings for water shipment over the least-costly alternative routing. Other objectives of navigation improvements include assisting in the development, safety and security of waterborne commerce; enhancing fish and wildlife; enhancing environmental quality; and enhancing social well-being. The importance to the nation of the inland waterways within the overall transportation network justifies continuing Federal responsibility for navigation improvements.

The study of future transportation challenges confronting the Ohio River provides an opportunity for public discourse on questions about where and when to increase system capacity, how to increase system reliability, and what roles existing operation strategies should play in the efficient and environmentally sustainable operation and maintenance of the Ohio River.

1.2 NEED FOR SYSTEMS ANALYSIS

Interdependence of traffic flows among the many individual elements of the system is a major problem in the economic evaluation of a lock-and-dam project. A change in the performance capabilities of one lock or channel segment can affect the efficiency of other components of the system. For example, the additional traffic accommodated because of improvements at J.T. Myers or Greenup locks and dams may increase delays at other projects in the system and thereby reduce the benefits for improvement. Similarly, other system projects can restrict traffic flows on the mainstem Ohio and prevent the materialization of the expected benefits of proposed navigation improvements. For this reason the evaluation methodology employed in this study measures the performance of the total navigation system. By evaluating the economic performance of the system for each plan of improvement, the impacts of specific improvements on the rest of the system are estimated and the marginal system benefits attributable to each plan can be measured. The plans that yield net system benefits can then be identified and compared.

The complex interrelationships and voluminous data dictate the use of computer modeling techniques. The Corps of Engineers, with the aid of various private economic and systems analysis consultants, has developed a set of transportation and economic models that incorporate statistical techniques to meet the needs of the analysis of a complex regional transportation system. The set consists of two distinct models: the Waterway Analysis Model (WAM) and the Ohio River Navigation Investment Model (ORNIM[1]). In general these models have been designed to help Corps planners achieve two goals: i) to operate and maintain the inland waterway network as efficiently as possible, and when necessary, ii) to select the best size, location, and timing of inland navigation waterway improvements.

The series of economic models employed in determining system benefits requires four main classes of data as inputs: i) data describing the navigation system, ii) data describing the equipment used on that system (towboats and barges for example), iii) data describing the origins and destinations, and tonnages of commodities shipped, and iv) data describing the costs of moving these commodities by barge and by overland modes of transportation.

Among of the more important components of the navigation system description are the (WAM) tonnage-transit curves for each lock being modeled. These curves describe the relationship between traffic levels and the time it takes a tow to transit a given lock. The tonnage-transit curves are used in ORNIM to estimate movement specific transit time and cost, the most variable component of total waterway transportation costs. Tracking the change in transit costs at different traffic levels and under different system assumptions (lock dimensions, number of locks, lock operating policies, and vessel fleets) allows the analyst to measure changes in waterway system benefits over time. **Attachment 1, Ohio**

[1] ORNIM was built by Oak Ridge National Laboratory (ORNL) in collaboration with the Navigation Planning Center of the Great Lakes and Ohio River Division (LRD). It is based on a long history of model development within the Corps beginning in the 1970s with the Tow Cost Model (TCM) and the Equilibrium Model (EQ).

River Navigation Investment Model (ORNIM) and **Attachment 2, Capacity Analysis**, provide full discussion of the ORNIM and WAM model, respectively.

1.3 FRAMEWORK OF ECONOMIC CONCEPTS

1.3.1 Background

At locks too small to efficiently handle higher traffic volumes or changing fleet configurations, congestion leads to degradation in service (reflected in higher transit times), which erodes rate-savings for all movements transiting the lock. Traffic-related service degradation has been the primary focus of lock improvement studies over the years, but reduced performance can be traced to causes other than increasing traffic volumes.

Aging projects and heavy usage can cause serious reliability concerns. In the Ohio River Navigation System (ORS), closures of the large main chambers lasting more than a couple of days are especially serious as this causes traffic to be processed in the smaller, less-efficient auxiliary chamber. During main chamber closures, the typically-sized Ohio River tow capable of transiting a main chamber in one 60-minute operation must move through the smaller auxiliary lock chamber in two operations lasting about 150-minutes. In this situation where the smaller auxiliary chamber carries the whole of the project's traffic, project performance is severely degraded. Service disruptions of this type result in longer transit times and higher transportation costs for those shippers relying on the affected lock.

Investments, including more aggressive maintenance, should be analyzed to determine the best course of action. From an economic viewpoint, investment that maximizes national economic development (NED) benefits is the best investment. The NED benefits are increases in the net value of the national output of goods and services and the NED evaluation is an incremental analysis between two future scenarios, or conditions. The future condition in the system without investment(s) is referred to as the without-project condition (WOPC), and the future condition with investment(s) is referred to as the with-project condition (WPC). In other words, the purpose of the analysis "... *is to estimate changes in national economic development that occur as a result of differences in project outputs with a plan, as opposed to national economic development without a plan.*"[2]

The established framework for answering these questions is described in the Principles and Guidelines. Identifying future scenarios or conditions is central to this framework. An economic analysis of these competing future conditions, over a 60-year planning horizon, seeks to estimate the stream of benefits and costs associated with each respective future. Estimating the contributions to National Economic Development (NED) benefits is accomplished by comparing with- and without-project futures to determine the incremental benefits or disbenefits of the WPC.

[2] Planning Manual, IWR Report 96-R-21, November 1996, page 56.

NED benefits for a navigation project investment are composed primarily of the reductions in transportation costs attributable to the availability of the improved waterway system. These reductions in transportation costs are achieved by increasing the efficiency of existing waterway movements, by providing for shifts of waterway and overland traffic to more efficient modes and routes, and by providing for shifts to more efficient origin-destination combinations. Further benefits accrue from traffic that is transported only because of the lower transportation cost from an improved project, and from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits are also realized from regional and national growth, and from the diversity in transportation modes. But, the conceptual basis for the "... *basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities.*"[3] These reductions in transportation costs can be classified as:

- Cost Reduction Benefits – transportation cost savings accrued to movements that move on the waterway under both with and without-project conditions, generated by a reduction in the economic cost of using the waterway. This can occur from reduced trip delays (expanded lock capacity and/or policies that reduce congestion) and / or increased shipping efficiencies (larger tow-size and/or heavier barge loadings).

- Shift-of-Mode Benefit – transportation cost savings accrued to movements that only move on the waterway under the with-project condition. These movements were transported on a different transportation mode at a higher cost under the without-project condition; the benefit is the difference between the costs of using the alternative mode without the project and the costs of using the waterway with the alternative under consideration.

- Shift of Origin-Destination Benefit – If the project would result in a shift in the origin of a commodity, the benefit is the difference in total costs of getting the commodity to its place of use with and without the project. If a project would result in a shift in the destination of a commodity, the benefit is the difference in net revenue to the producer with and without the project. The shift of origin-destination benefit cannot exceed the reduction in the transportation charges achieved by the project.

- Induced Movements Benefit – This benefit applies if a commodity or additional quantities of a commodity would be transported only because of lowered transportation charge with the project. The quantities are limited to increases in production and consumption resulting from lower transportation costs. An increase in waterway shipments resulting from a shift in origin or destination is not included. The new movement benefit is defined as the increase in producer and consumer surplus; practically, it can be measured as the delivered price of the commodity less all associated economic costs, including all of the costs of barge transportation other than those of the navigation project. This benefit cannot exceed the reduction in the transportation charges achieved by the project.

[3] ER 1105-2-100, 28 December 1990, page 6-55.

Economic analysis of waterway infrastructure service degradation focuses on the evaluation and comparison of the existing waterway system with alternative measures: 1) increasing capacity (decreasing transit times and thereby reducing delay costs); or 2) increasing reliability (replacing or rehabilitating aging structures, thereby reducing the probability of structural failure and its consequences). This analysis can be described within a supply and demand framework.

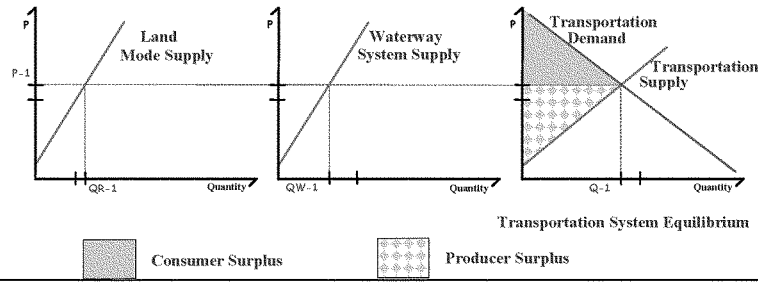
Again, the primary benefit for Federal investment in the inland waterways is the collective transportation cost savings for barge shipment over the least-costly alternative routing. The benefit, generally referred to as transportation rate-savings, also accounts for any differences in transportation costs arising from loading, unloading, trans-loading, demurrage, and other activities involved in the point-to-point transportation of goods. Estimating waterway investment benefits requires an analysis of: 1) waterway transportation demands; 2) transportation costs for the waterway routing; and 3) transportation costs for the least-costly all-overland alternative routing.

1.3.2 Theoretical Framework

This section provides the economic foundation for the development and application of ORNIM as discussed in the next section (1.3.3). The Corps, and therefore ORNIM, must be consistent with established Principles and Guidelines when estimating the benefits of river system improvements. The Principles and Guidelines (P&G), which were published in March 1983, provide general guidance for doing benefit assessments. P&G leaves open for the analyst to improve their tools and assessments as new data become available and computational capabilities improve. ORNIM is a reflection of the Corps' recognition that a new state-of-the-art is possible.

Assume there is some upward sloping supply curve for land and water transportation as shown in **Figure 1-1**. The supply can be added horizontally to derive the supply curve for transportation. Since the land and water modes are assumed perfect substitutes, the demand curve for transportation can be found by horizontally summing individual movement demands. The intersection of system supply and demand gives the without-project condition market equilibrium at P-1 with an equilibrium system traffic level of Q-1 (QR-1 moving via land and QW-1 moving via waterway). The total benefit of the transportation system is the consumer surplus above P-1 and under the demand curve and the producer surplus below P-1 and above the system supply curve.

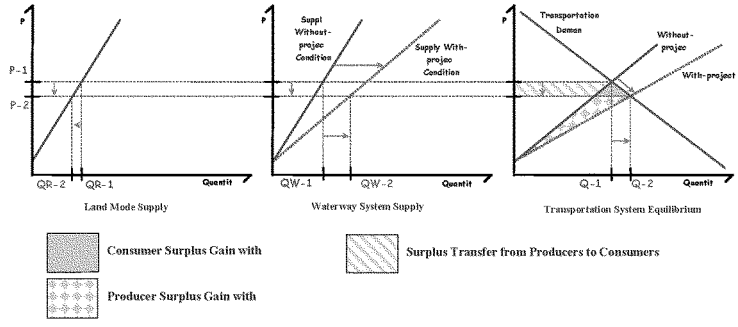
FIGURE 1-1
Transportation System Equilibrium - WOPC Benefits



A distinction should be made between the demand for commodities (coal, grain, etc.) and the resulting derived demand for transportation of these commodities. The demand for transportation is a derived demand driven by the demand of the commodities seeking transportation, which are in turn driven by the demand for the end products produced by these commodities. The demand for the end products is driven by such things as population, technology, relative prices of competing and complementary goods, income and individual tastes and preferences. The demand for barge transportation and the demand for land transportation are interdependent and are affected by the market clearing price in the transportation sector.

With an improvement to the waterway navigation system, the waterway supply curve will shift to the right (assuming the navigation investment result in lower transportation costs for all levels of quantity supplied). This shift results in a shift of the total transportation supply and results in a new system equilibrium at a lower price P-2 and a higher system equilibrium traffic level of Q-2 (land traffic is reduced while total traffic and water traffic increase). Subsequently, the incremental benefit of the with-project condition comes from consumer and producer surplus gains, with a shift of surplus from producers to consumers as shown in **Figure 1-2**.

FIGURE 1-2
Transportation System - Incremental WPC Benefits

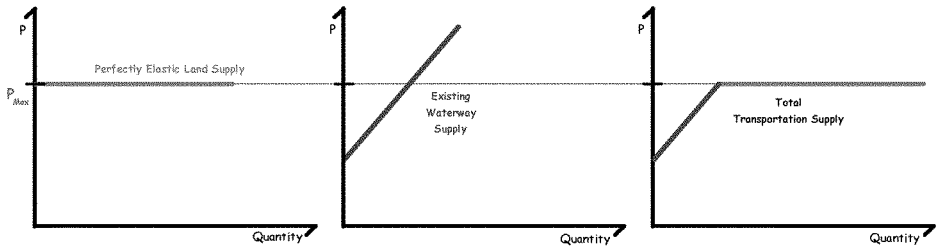


In addition, the with-project increase in quantity of transportation demanded shown in Figure 1-2 above, results from an increase in water transportation demand (QW-1 to QW-2) relative to land transportation demand (QR-1 to QR-2) as water transportation becomes more competitive. Transportation system equilibrium traffic increases from Q-1 to Q-2 and costs reduce from P-1 to P-2

The Corps guidelines for estimating waterway benefits were established in the 1950s through a "*mutual understanding*" between the water resource agencies. The first such understanding was recorded in the Federal Inter-Agency River Basin Committee's *Proposed Practices for Economic Analysis of River Basin Projects* in May 1950 (U.S. Senate), and later revised in May 1958. In that report, referred to as the Green Book (because of the color of its cover), navigation benefits were identified as the difference

between the total "*...cost of transportation by an alternative means and the non-project or associated cost of transportation by waterway.*" In other words, guidance allows the conservative assumption of a totally elastic supply of land transportation. This caps the equilibrium price of transportation at the land price and limits the willingness-to-pay for water transportation. As shown in **Figure 1-3**, assuming land and water are perfect substitutes, the maximum transportation price is P_{max}.

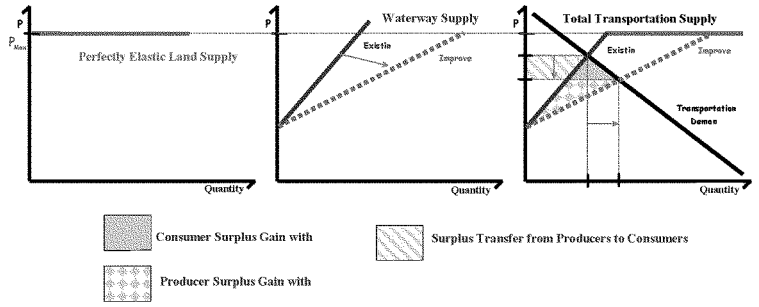
FIGURE 1-3
Conceptual Supply Curves



The effect of perfectly elastic land supply on equilibrium is a function of the relationship between the land supply price, the water supply curve and transportation demand. Four situations can occur: i) land supply price is greater than all quantities of water supply and all demand is met by water mode; ii) land supply price is less than any quantity of water supply and all demand is met by land mode; iii) land supply price is less than any quantity of existing water supply, but not for all quantities of the improved water supply; or iv) demand is met with a combination of land and water supply.

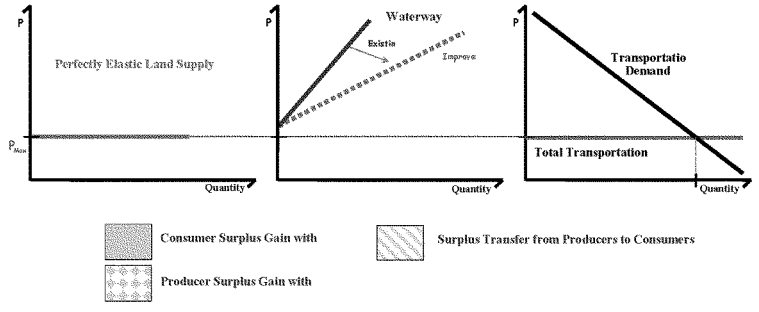
In the first case, where the land supply price is greater than all quantities of water supply and all demand is met by water mode (**Figure 1-4**), consumer surplus, producer surplus and a surplus transfer from producers to consumers occurs under a water supply increase (improvement) as previously shown in **Figure 1-2**. In this case the land rate is actually immaterial in the determination of benefits (with project incremental transportation savings) and the demand for barge transportation is equivalent to the total transportation demand. Corps regulations define these benefits as "Cost Reduction Benefits."

FIGURE 1-4
System Equilibrium Assuming Elastic Land Supply – CASE 1



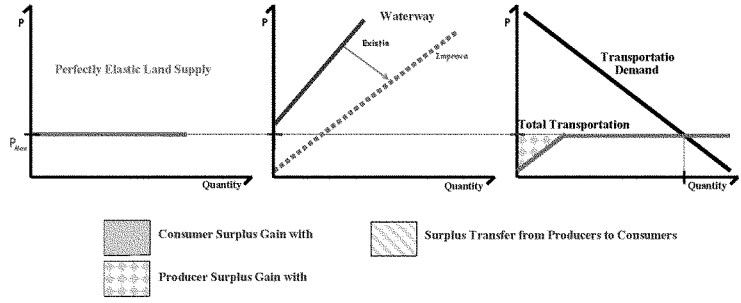
In the second case, where the land supply price is less than all quantities of water supply under the existing water system and under the improved water system, all demand is met by the land modes (**Figure 1-5**). In this case there is no surplus generated by a waterway improvement. Situations where the water improvement can supply transportation less than the land mode price are handled under case 3 below.

FIGURE 1-5
System Equilibrium Assuming Elastic Land Supply – CASE 2



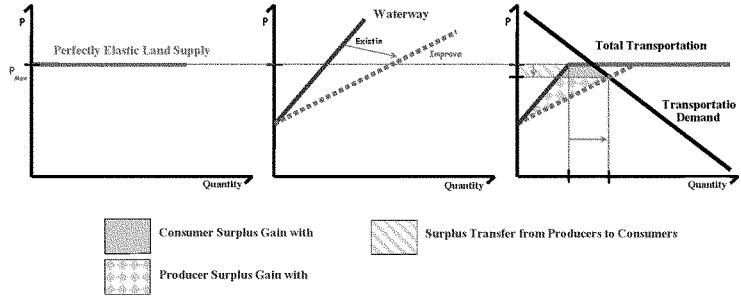
In the third case, water supply is only used under the improved water supply condition (**Figure 1-6**), and only producer surplus is produced under a water supply increase (improvement). The equilibrium quantity of transportation supply remains constant, however, some traffic is shifted from the land mode to the water mode. If the supply of water transportation increases enough, all land mode traffic could shift to water transportation, and even additional demand could be met. Corps regulations define these benefits as "Shift-of-Mode Benefits."

FIGURE 1-6
System Equilibrium Assuming Elastic Land Supply – CASE 3



In the fourth case, there is a combination of land and water supply being used to meet demands (**Figure 1-7**), consumer surplus, producer surplus and a surplus transfer from producers to consumers occurs under a water supply increase (improvement) as previously shown in **Figure 1-2** and **Figure 1-4**. In this case there is a combination of "Cost Reduction" and "shift-of-Mode" benefits.

FIGURE 1-7
System Equilibrium Assuming Elastic Land Supply – CASE 4



This assumption of a perfectly elastic land supply reduces the problem to an analysis of the demand for barge transportation (not total transportation) and the supply of barge transportation (not total transportation); to calculate the incremental transportation savings for a waterway improvement, the quantity of demand supplied by land modes is not needed[4].

[4] The quantity of land mode traffic is needed if externality costs are calculated.

1.3.3 Model Framework

ORNIM can be described as a spatially-detailed, partial-equilibrium model. It is not designed to estimate the total benefits of a river system, nor the benefits the nation would lose if the river system no longer existed. A more general equilibrium model would be needed to assess the total value of a river system. ORNIM is appropriate to estimate the benefits of incremental improvements to a river system. ORNIM has been described as a transportation planning model. A comprehensive transportation planning model conducting general equilibrium freight transportation supply and demand analysis can involve many complicated simultaneous decisions using multiple economic agents, with spatial and time dimensions. A typical four-step transportation planning model treats trip generation, trip distribution, mode choice, and route assignment endogenously. ORNIM, however, focuses on mode choice, or more specifically modal diversion from water transportation, with trip generation and distribution handled exogenously through traffic forecast inputs. Routing can be assigned by ORNIM, but routing is typically not an issue in Ohio River Basin (ORB) waterway studies because multiple water routes do not exist.

ORNIM operates within a supply and demand framework with inputs that model the supply of water transportation and the demand for water transportation. Demand is represented by the willingness-to-pay[5] for waterway services by rank-ordering all waterway commodity movements and their transportation rate-savings. Supply is represented by the cost of the waterway service with lock performance tonnage-transit curves developed from the WAM (see **Attachment 2, Capacity Analysis**).

1.3.3.1 Supply

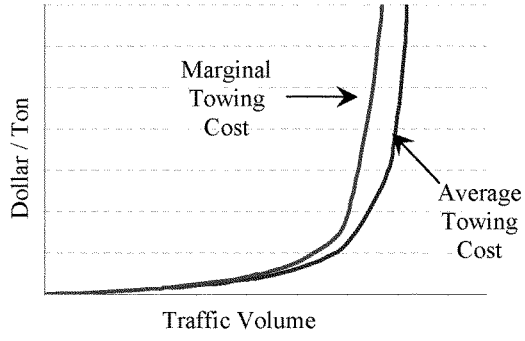
On the supply side, or the performance/cost curve side, the supply curve represents, for every level of traffic, the shipper cost of shipping commodities via the water routing. Two waterway cost curves are depicted in **Figure 1-8** -- the average towing cost (ATC) curve and the marginal towing cost (MTC) curve. The ATC curve represents the average cost of shipping at different traffic levels. It rises because the average delay, and therefore the average cost, is higher at higher levels of traffic. The MTC curve represents the additional cost to the shipping industry of transporting an additional ton of cargo on the waterway. It increases at a faster rate than the ATC because the higher delays associated with higher levels of traffic are sustained by all shippers, not only the shipper who causes the delay. The costs shown include only those costs borne by the shippers (e.g., equipment, labor, fuel, and supplies), and not those borne by the Federal Government in the operation and maintenance of the waterway system.

Shippers in the inland waterway operate in their own self-interest. Individual shippers will not restrict output to a social optimum, where the last increment of tonnage added to the system exhibits just enough marginal rate savings to offset the marginal towing costs (including induced delays) (MRS=MTC). Instead, shippers tend to expand waterway volumes to the level at which their marginal rate-savings or demand is just equal to average towing cost (MRS = ATC). This occurs because an individual carrier pays only

[5] A proxy measure of willingness-to-pay is developed from the rate differential between existing water routing and least cost alternative routing.

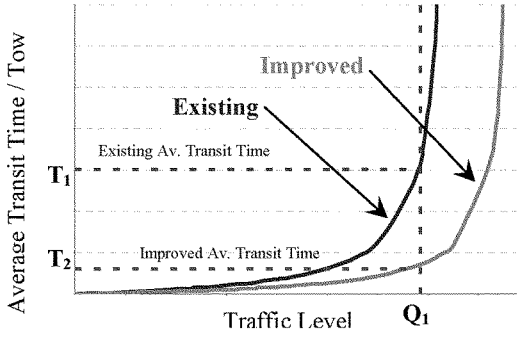
its shipping costs and does not pay the true cost to society (i.e. the increased costs its use of the waterway imposed on other shippers in the form of additional delays). For example, in a congested lock situation, the addition of just a few more tows per day causes lock delays to increase exponentially because of the queuing effect. The additional tows do not pay for the total marginal increase in tow delay. Rather, the increased delay costs are spread among all tows using the congested lock, making each less efficient. For this reason, the ATC is used in the analysis of inland navigation projects.

FIGURE 1-8
Conceptual Waterway Supply Curves



Tonnage-transit curves are developed with lock performance monitoring system (LPMS) timing data in the WAM. The curves are used to represent the transit time relationship with volume of traffic serviced under different alternatives (**Figure 1-9**) and can be used to value the resources required to transit the project under without- and with-project conditions. Since the cost of waterway transportation is a function of transit times in the system, costs under both situations can be estimated. For a given quantity of traffic (Q_1), average transit time under the existing condition is T_1. Under an improved condition the average transit time drops to T_2. In this situation, waterway transportation costs for the shippers are reduced.

FIGURE 1-9
Tonnage-Transit Curves, Existing vs. Improved



1.3.3.2 Demand

System demand is modeled with waterway commodity movements ranked in descending order of transportation rate-savings. The rate-savings serve as a proxy for willingness-to-pay. The least-cost alternate route cost is used to measure willingness-to-pay for movements on the waterway system because we assume that a shippers' marginal willingness-to-pay is the difference in transportation costs between the waterway routing and the least-cost all-overland routing. As a result, the system demand curve represents the marginal system rate-savings (MRS) or marginal benefit curve. The demand (MRS) curve represents, for different levels of traffic, shippers' marginal willingness-to-pay for the use of the waterway. If the alternative mode offers lower transportation costs (negative rate-savings for the waterway routing), then the alternate routing will be used. If the waterway and alternative routing costs are the same (zero rate-savings), then the shipper is indifferent as to the mode/route used. If the alternative routing costs are higher (positive waterway rate-savings), the waterway routing will be used with the incentive (or willingness-to-pay) for using the waterway increasing as the savings for using the waterway increases.

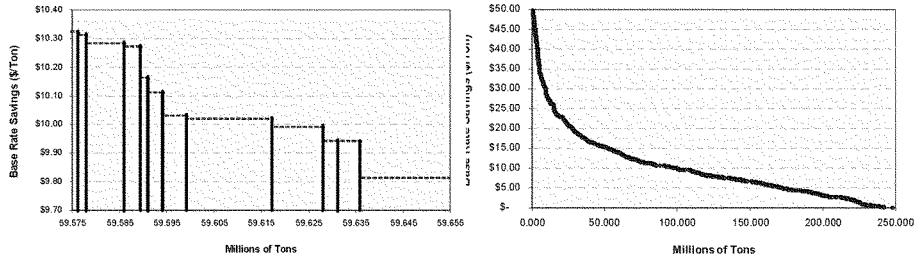
Corps regulations require that NED benefits be based on long-run marginal costs. Shippers make transportation decisions based on the rates they are actually charged. In competitive markets, rates (prices) correspond to marginal cost, and given market stability, prices will settle at long-run marginal costs. Transportation rates are used to estimate the long run marginal cost of waterway transportation.

The rank ordered waterway transportation rate-savings curve (system demand for barge transportation) is developed off port-dock barge level WCSC data. The origin-destination-commodity (ODC) movements for this "base" year are rated and forecast into the future. As a result, this represents a forecast for water transportation demand and not a forecast of total demand for the commodities between the ODC triplicates[6]. For each movement, the water transportation rate for the base year is subtracted from the least-costly all-overland rate for the base year to derive the "base rate-savings" which is assumed to be the willingness-to-pay for barge transportation.

A distinction should be made between movement level demand (individual) and system demand. System demand is simply the horizontal summation of individual movement demands. System demand is elastic while individual movement demand is assumed (and modeled) inelastic as shown in **Figure 1-10**; the market or system demand curve is a sorted aggregation of the inelastic individual movement demands. The aggregate demand curve plots the willingness-to-pay, associated with each movement in the system. The result is a set of discrete points representing numerous individual demands.

[6] Induced demands are handled through separate studies.

FIGURE 1-10
System Demand for Barge Transportation



Source: 1999 ORS WCSC flows with FY00 rates aggregated to unique ORNIM port, 9-group commodity and 12-group barge type.

1.3.3.3 Equilibrium

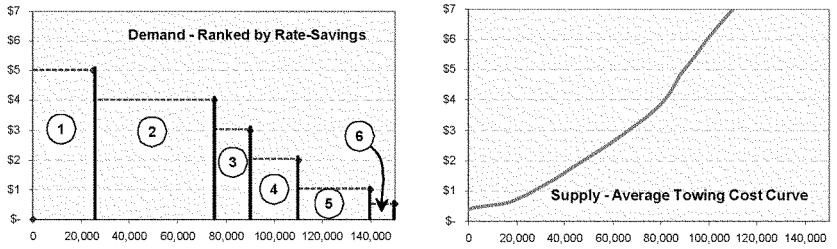
Projecting future system benefits necessarily involves being able to project future equilibrium traffic levels on the waterway system and the resulting transportation rate-savings for each movement. In order to understand the model's determination of system equilibrium traffic levels and its calculation of benefits, an example of six waterway movements is constructed and shown in **Table 1-1**. Other important assumptions in this example are that the system only contains one navigation project and each movement shares similar fleet characteristics (e.g. same tow-sizes, empty returns, etc.).

TABLE 1-1
Example of System Movements

Movement Number	WW Demand Tonnage	Rate ($/ton)		Base Rate-Savings ($/Ton)
		Water	Land	
1	25,000	$ 5.00	$ 10.00	$ 5.00
2	50,000	$ 4.00	$ 8.00	$ 4.00
3	15,000	$ 3.00	$ 6.00	$ 3.00
4	20,000	$ 2.00	$ 4.00	$ 2.00
5	30,000	$ 1.00	$ 2.00	$ 1.00
6	10,000	$ 0.50	$ 1.00	$ 0.50

In this example the system supply cost curve is analogous to the project's tonnage-transit curve (**Figure 1-9**) except that the Y-axis is converted to a dollar-per-ton value by multiplying the average transit time by the average hourly equipment costs and dividing by the tonnage moved. This transforms the tonnage-transit curve into the average cost curve shown in **Figure 1-8**. In other words, supply constraints on the existing waterway rate are assumed to be caused only by traffic congestion and the delay-costs this congestion imposes upon the system. The system demand curve is represented by an ordering of the six commodity movements sorted from highest to lowest rate-savings (**Figure 1-11**).

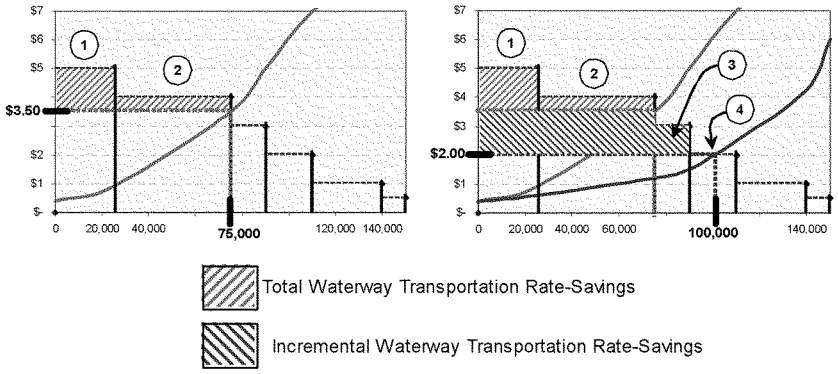
FIGURE 1-11
System Curves



Since the shippers' marginal willingness-to-pay is measured as the difference in transportation costs between the waterway routing and the least-cost alternative routing, if the alternative mode offers lower transportation costs (negative rate-savings for the waterway route), then the alternate route will be used. If the waterway and alternative route costs are equal (zero rate-savings), the shipper is indifferent as to the route (mode) used. If the alternative route costs are higher (positive waterway rate-savings), the waterway route will be used with the incentive for using the waterway increasing as the savings for using the waterway increases.

As shown in **Figure 1-12**, all of movements 1 and 2 move via waterway under the existing system configuration. The system equilibrium tonnage will be 75,000 tons. At equilibrium, the average waterway cost will be an additional $3.50 per ton above the rate base, leaving an "eroded" base-rate savings of $1.50 for movement 1 and $0.50 for movement 2. The resulting system-rate savings is $62,500 ($1.50/ton X 25,000 tons plus $0.50/ton X 50,000 tons). With an improvement at the lock, transit costs are lowered and a new system equilibrium with additional average waterway cost lowered to $2.00 per ton is the result. At this lower cost, system tonnage equilibrium of 100,000 tons is reached. Movements 1 and 2 experience a cost-reduction benefit of $112,500 ($1.50/ton X 75,000 tons) and with the lower waterway transportation costs, all of movement 3 and some of movement 4 move on the waterway. This additional waterway tonnage represents shift-of-mode tonnage. In our example displayed in **Figure 1-12** shift-of-mode benefits would be $15,000 ($1.00/ton X 15,000). Note there are no shift-of-mode benefits generated for the marginal movement (movement 4) unless the entire movement is moved and the cost curve crosses below the base rate-savings. This is because equilibrium-adjusted-base-rate savings for movement 4 equals $0.00.

FIGURE 1-12
System Equilibrium



In reality, ORNIM considers the cost curves for multiple locks with thousands of movements each with unique origins and destinations, and cost characteristics. ORNIM iterates to determine the equilibrium level of traffic where every movement that has a cost advantage on the waterway moves on the waterway. As different mixes of movements are considered in the system, each project is affected differently resulting in different average transit times at each project. The movements transit many different combinations of projects. The increase in transit time is translated into a cost increase for each movement taking into account its specific cost characteristics. For example, liquid commodities that have a shipping plan in 1 tanker barge tows have higher cost increases than dry cargo commodities moving in 15-barge open hopper tows. A detailed step by step discussion of the equilibrium process is given in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)**.

1.4 RISK AND UNCERTAINTY

Corps of Engineers guidelines as presented in the Principles and Guidelines have long recognized that uncertainty is inherent in all phases of the analysis of waterway investments. As such, this analysis provides information regarding the level of uncertainty associated with the values estimated for a number of critical inputs. These include traffic demand projections, lock performance descriptors (capacity and lock availability), and structural reliability. Estimating values for these inputs rests upon a large set of variables, many of which are unique to the input being estimated.

This study focuses its descriptions of uncertainty on the key determinants of economic feasibility--traffic demand projections, lock performance and structural reliability. In the case of traffic demand projections, alternative traffic forecast scenarios based upon competing sets of assumptions are presented and analyzed (**Attachment 4, Traffic Demand Forecasts**). Discrete event simulations based upon statistical analysis of tow operator behavior and actual lock operations are used to estimate traffic-delay or transit relationships at all locks (**Attachment 2, Capacity Analysis**). Lock availability

and performance is further described through the use of hazard values and event trees (**Attachment 3, Project Maintenance Analysis**), which is the key input into the Monte Carlo-type simulation which calculates expected future adverse impacts associated with a lock's structural reliability (**Attachment 1, ORNIM**).

1.5 APPENDIX ORGANIZATION

The remainder of this appendix is organized into the following major topical sections. **Section 2** describes the resources and economy of the six-state study area. **Section 3** highlights the industries dependent upon the waterways. **Section 4** describes the navigation system that was analyzed to determine the extent and magnitude of impacts resulting from any system improvements. **Section 5** analyzes the vessel fleet and the performance characteristics of the Ohio River. **Section 6** discusses the historic and projected traffic demands. **Section 7** describes the system benefit evaluation process, including the system model used, major model inputs, and the results of model calibration. **Section 8** identifies and evaluates the Ohio River mainstem without-project condition. **Section 9** identifies and evaluates alternative investment plans and **Section 10** presents the economically justified Ohio River mainstem navigation system investment plan (SIP).

Seven attachments complement this appendix. **Attachment 1** provides a thorough discussion on the economic model used in the analysis. **Attachment 2** discusses the tonnage-transit curves used in the economic analysis. **Attachment 3** describes how component reliability is used to develop and evaluate maintenance alternatives. **Attachment 4** documents development of traffic demand forecast scenarios used in the analysis. **Attachment 5** discusses current traffic management schemes deployed on the mainstem Ohio River during lock closures and **Attachments 6 and 7** describe the transportation rates used in the analysis and the results of our efforts to accumulate information on waterway shipper responses to changes in the price of waterway transportation.

Section 2
BASIN RESOURCES AND ECONOMY

2.1 GENERAL

The region served by the Ohio River navigation system (ORS) is a rectangular-shaped area roughly bounded on the east by the Allegheny Mountains, on the west by the Mississippi River, on the north by the Great Lakes, and on the south by the Tennessee River. The Ohio River bisects the study area in a northeast to southwest direction. The eastern portion of the study area is characterized as generally mountainous, giving way to eroded uplands with vast reserves of coal. The western area is characterized as generally rolling terrain, which gives way to the eastern prairie lands of Illinois. **Figure 2.1** illustrates the navigable rivers of the Ohio River Basin (ORB).

The ORB's topography is diverse. This diversity has produced an economic benefit to the region by promoting the development of its industries. The terrain varies from the hilly regions of the Appalachian range and Great Smokies to the rolling plains of Indiana and Illinois. Each of these topographical environments promoted a distinct type of economic specialization, and the exchange of the region's industrial resources and products by barge and other modes of transportation has promoted its industrial development.

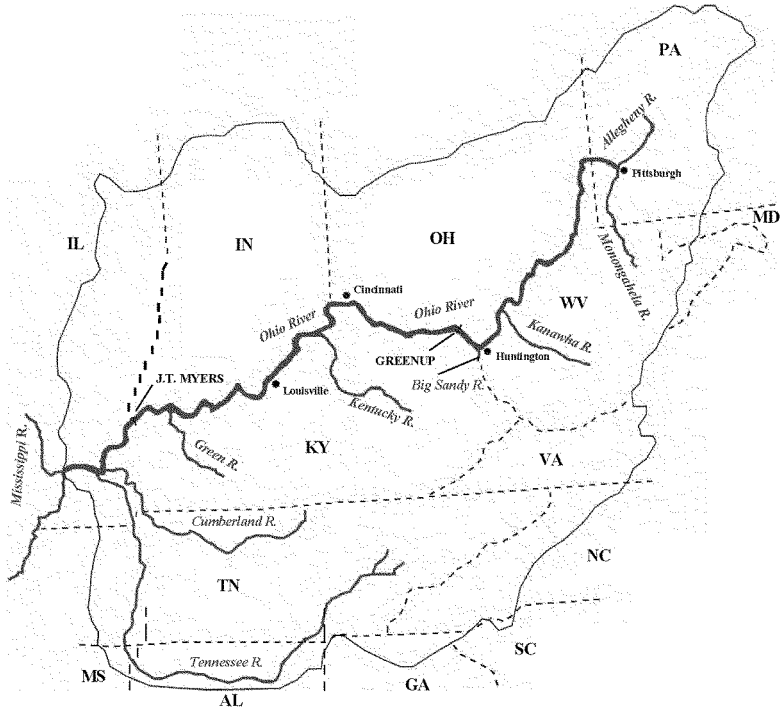
The population of the ORB states and waterside economic areas (BEAs) is 55 million, or 21 percent of the national total. Although the population is distributed throughout the area, there are six major population centers in the region: Indianapolis, Columbus, Nashville, Pittsburgh, Cincinnati and Louisville, the last four of which are located on navigable Ohio River Basin waterways. These and smaller riverside cities, like Charleston and Huntington, WV; Evansville, IN; and Knoxville, TN, are indicative of the population concentration in the basin's river valleys. **Table 2-1** shows trends in population, employment, and earnings for ORB states, for BEA areas in or near the basin, and for the country from 2000 to 2003.

Extensive coal deposits, abundant limestone reserves, fertile soils, abundant water supplies, and extensive woodlands are the area's principal resources. These resources, along with less extensive deposits of crude oil, natural gas, glass sands, clays, and minerals such as salt, zinc and copper, supported initial settlement of the area and the development of its first industries—coal mining, farming, chemical manufacture, meat packing, glass making, pottery, petroleum refining, and steel manufacturing. Some of these are still major industries in the region, most notably the steel, chemical, and coal mining industries.

In the ORB's major cities the economy is robust and diversified, depending upon services and technology, and much less on manufacturing. The smaller cities still rely heavily upon manufacturing (especially steel, automobile and aluminum production), while the hinterlands are still heavily dependant upon extractive industries (especially coal

mining) and farming. The regional sectors of highest importance to waterway traffic are coal mining and their primary customer, electric utilities; stone quarrying and construction; farming; and manufacturing.

FIGURE 2-1
Ohio River Basin



2.2 HISTORICAL PERSPECTIVE

The dominant influences during the early settlement and growth of the region were the rich soils, favorable climate, dense forests, and numerous waterways providing transportation arteries. Mineral resources, particularly coal, salt, limestone, oil, and gas also became important in molding the regional economy.

Agriculture was the foundation of the ORB economy. Farm employment accounted for over sixty percent of total employment in 1850. Agriculture continued to dominate until the early years of the 20th century. At that time, great strides in agricultural productivity released manpower resources from farming, making them available for manufacturing employment. By 1925, employment in manufacturing exceeded employment in agriculture.

TABLE 2-1
Population, Employment and Earnings for Waterside ORB States and BEA Areas Compared to the United States

BEA City Name	Population (thousands)		Avg. Ann. % Change	Employment (thousands)		Avg. Ann. % Change	Earnings (millions)		Avg. Ann. % Change
	2000[2]	2003[3]	2000-03	2000[2]	2003[3]	2000-03	2000[2]	2003[3]	2000-03
Atlanta-Sandy Springs-Gainesville, GA-AL	6,194	6,594	2.11%	295	386	9.34%	5,547	9,160	18.20%
Knoxville-Sevierville-La Follette, TN	1,085	1,121	1.09%	359	536	14.28%	6,529	12,491	24.14%
Lexington-Fayette-Frankfort-Richmond, KY	1,444	1,468	0.55%	690	894	9.03%	13,441	19,261	12.74%
Charleston, WV	1,207	1,202	-0.14%	516	568	3.27%	11,094	13,128	5.77%
Cincinnati-Middletown-Wilmington, OH-KY-IN	2,215	2,252	0.55%	892	1,259	12.16%	19,053	33,913	21.19%
Columbus-Marion-Chillicothe, OH	2,468	2,534	0.88%	928	1,362	13.65%	18,562	34,541	23.00%
Pittsburgh-New Castle, PA	2,981	2,953	-0.31%	171	158	-2.54%	3,958	3,548	-3.58%
Cleveland-Akron-Elyria, OH	4,693	4,688	-0.04%	2,294	2,652	4.95%	53,206	72,192	10.71%
Evansville, IN-KY	743	749	0.27%	404	481	6.02%	7,973	10,847	10.81%
Louisville-Elizabethtown-Scottsburg, KY-IN	1,461	1,491	0.68%	630	819	9.16%	12,397	20,248	17.77%
Nashville-Davidson-Murfreesboro-Columbia, TN	2,446	2,527	1.09%	894	1,413	16.48%	15,137	34,762	31.93%
Paducah, KY-IL	240	240	0.00%	97	123	8.23%	1,756	2,776	16.49%
Memphis, TN-MS-AR	1,931	1,959	0.48%	783	1,060	10.62%	13,871	26,853	24.63%
Huntsville-Decatur, AL	1,000	1,017	0.56%	373	534	12.71%	6,988	12,946	22.82%
Tupelo, MS	533	534	0.06%	259	315	6.71%	3,772	6,249	18.33%
St. Louis-St. Charles-Farmington, MO-IL	3,258	3,311	0.54%	1,595	2,017	8.13%	33,411	52,515	16.27%
Total	33,899	34,640	0.72%	11,180	14,577	9.25%	226,695	365,429	17.25%
BEAs % of U.S.	12.0%	11.9%		6.7%	8.7%		3.5%	5.1%	
United States	282,192	290,789	1.01%	166,759	167,174	0.08%	6,504,679	7,113,751	3.03%
Eight ORB States									
Alabama	4,452	4,504	0.39%	1,714	2,305	10.38%	76,977	55,165	-10.51%
Illinois	12,440	12,649	0.56%	5,745	7,017	6.89%	313,024	213,535	-11.97%
Indiana	6,092	6,200	0.59%	2,670	3,469	9.12%	125,272	88,071	-11.08%
Kentucky	4,049	4,118	0.56%	1,644	2,170	9.69%	73,872	50,164	-12.10%
Ohio	11,364	11,438	0.22%	5,203	6,525	7.84%	244,121	173,530	-10.75%
Pennsylvania	12,286	12,371	0.23%	5,563	6,610	5.92%	268,169	184,716	-11.69%
Tennessee	5,703	5,845	0.82%	2,227	3,254	13.47%	117,216	90,650	-8.21%
West Virginia	1,807	1,811	0.07%	781	859	3.22%	26,951	19,127	-10.80%
Total	58,193	58,936	0.42%	25,547	32,209	8.03%	1,245,602	874,958	-11.11%
Percent of U.S.	20.6%	20.3%		15.3%	19.3%		19.1%	12.3%	

Source: [1]http://www.bea.doc.gov/bea/regional/reis (BEA Economic Areas, Table CA1-3-Population)
[2]http://www.bea.doc.gov/bea/regional/reis/ (SIC industry 1969-2000)
[3]http://www.bea.doc.gov/bea/regional/reis/ (NAICS industry 2001-2003)

By the 1920s, newly developed technologies and consumer goods – including automobiles, airplanes, telephones, and radios – led to a surge in national demand for manufactured goods. Each of these new industries and products enhanced the economic desirability of upgraded and expanded highway, rail, air, and water networks. The increased demand for coal to stoke industrial boilers, fuel trains, charge blast furnaces, produce steam for the generation of electricity, and to provide heat to homes and factories necessitated the more rapid development of the inland waterway infrastructure.

Since World War II, the trend toward increased manpower resources in manufacturing and mining has abated. Most industries have made great technological strides in productivity. The demand for labor in manufacturing has decreased while the demand for labor in services has increased. The shift in employment from manufacturing to services has coincided with a major demographic shift in the United States. People and markets have tended to shift to the south and southwest as the nation's population has sought more favorable climate and living conditions.

The industrial shift towards services had detrimental consequences on the ORB economy in the 1980s. The resulting economic downturn meant a loss of jobs, earnings and tax base in the basin. The most visible effect of these forces was the massive rationalization of the steel industry.

2.3 RESOURCES

2.3.1 Coal

Coal traffic currently accounts for over 55 percent of all tonnage shipped on the Ohio River with 80 percent going to waterside electric generating plants. Coal reserves are extensive in the basin, and the availability of low-cost coal is largely responsible for the establishment and growth of manufacturing in the area. Coal was key to the development of the steel industry, which dominated the economy of the Pittsburgh area for over a century, and to the electric generating industry, whose low cost made the area attractive for a wide range of industries.

Coal is found in abundance in the basin (see **Figure 2.2**), but with the major seams located in the eastern section. The western reserves within the basin are not only less abundant, but have characteristics that are significantly different, reflecting the different geologic forces that created the coal. Bordering the river down to Huntington, the coal is generally high energy and low to medium in sulfur content. The seams extending southward from Pennsylvania's Allegheny River valley through eastern Ohio, West Virginia, Virginia, eastern Kentucky, and on into Tennessee are referred to as the Appalachian coalfields. The seams in Illinois, Indiana, and western Kentucky are referred to as the Illinois Basin, a subset of the larger Interior coalfields. Both Appalachian and Illinois Basin deposits are bituminous coals of relatively high energy content, especially when compared with the sub-bituminous coals of Wyoming's Powder River Basin (PRB).

The more important characteristics of coals are sulfur content and heat content (BTU). The Appalachian coals are generally lower in sulfur content than the Illinois Basin coals, though higher in sulfur content than the PRB coals. ORB coals have higher BTU content than PRB coals. Sulfur is an undesirable element in a particular grade of coal's makeup. Known coal resources in the ORB with sulfur and BTU content are shown in **Table 2-2**. Since 2000, basin population and earnings have grown less than the national average while employment has grown by more than the national average (see Table 2-1). The eight ORB states comprise about 25 percent of the nation's population, employment and earnings.

Ohio River Basin coal producers account for nearly one-half of national coal production. Coal production levels in the ORB are listed in **Table 2-3**. Production levels vary by decade between the tributary basins, but it has been relatively constant for the ORB as a whole at about 350 million tons a year. Production is highest in the low-sulfur coalfields of central Appalachia (Big Sandy and Kanawha river basins) followed by production in northern Appalachia (Allegheny and Monongahela river basins). Though most of the coal produced in the basin is consumed in the basin, coals from the northern Appalachian fields are especially valuable as metallurgical coals used in the steel-making process throughout the United States and the world. High quality (low sulfur and high-energy content) coals from these same fields are used to generate electricity throughout the Eastern and Midwestern United States and in Canada, Asia, and Europe.

FIGURE 2-2
Ohio River Basin Coal Reserves

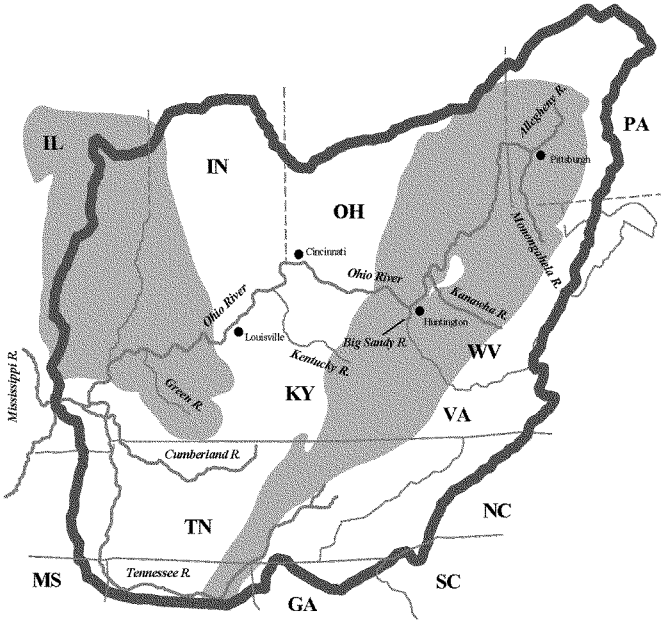


TABLE 2-2
Sulfur and BTU Content of Basin Coal Resources

Tributary Basin	Millions of Tons	Sulfur*	BTU
Allegheny	3,895.3	2.86	13,353
Big Sandy	16,793.4	0.81	15,155
Cumberland	1,588.5	2.32	13,550
Green	7,337.8	3.90	12,810
Kanawha	29,908.1	0.97	14,050
Kentucky	1,646.5	0.90	13,103
Monongahela	16,889.3	2.43	13,402
Ohio	39,605.2	3.37	12,984
Tennessee	264.6	1.77	13,473
Total	148,288.6	2.44	13,406

* Sulfur content is measured in pounds per million BTU

Source: Resource estimates from "National Coal Resource Assessment, 2000 Resource Assessment of Selected Coal Beds and Zones in the Northern and Central Appalachian Basin Coal Regions, USGS
Sulfur and BTU content from EIA, disk cn6530.hb2.reserve.base.data

TABLE 2-3
Coal Production in Ohio River Basin
(Millions of Tons)

River Basin	1970	1980	1990	2000
Allegheny	14.6	14.1	10.5	5.1
Big Sandy	79.7	90.7	120.6	101.6
Cumberland	1.8	5.1	3.8	0.8
Green	48.0	31.9	31.8	18.1
Kanawha	59.0	48.0	71.0	79.3
Kentucky	3.4	7.7	5.2	1.0
Monongahela	62.8	48.0	53.2	66.9
Ohio	75.5	61.9	77.7	66.5
Tennessee	6.4	7.8	4.4	2.7
Ohio River System	351.3	315.3	378.4	342.0
East of Mississippi	567.8	578.7	630.2	509.3
U.S. Total	612.7	829.7	1,029.1	1,075.5

Sources: Minerals Year Book 1970, Bureau of Mines; Coal Production 1980 and 1990, Energy Information Administration; http://www.eia.doe.gov/cneaf/coal; and Annual Energy Review 2000, EIA

Despite over a century of mining, the area still contains large reserves of coal that are sufficient to meet the nation's expected needs for several centuries to come. As shown in **Table 2-4**, over one-quarter of the nation's coal reserves and over 90 percent of its highest energy reserves lie in the Ohio River Basin. At current production rates, the basin's reserves are sufficient to continue producing coal within the basin for the next 350 to 400 years.

2.3.2 Soils

The western basin farms of Illinois, Indiana, and Ohio rest upon the eastern extremity of the nation's most fertile soils equaled in the world only by the pampas of Argentina and the Ukraine's chernozem grasslands. Agriculture in these states, and to a lesser extent in western Kentucky, revolves around the cultivation of corn, soybeans, and wheat, in that order. In 1996, these first three states accounted for 26 percent of the nation's corn production and 32 percent of soybean production. They represent 3.7 percent of the land area of the U.S., 11.1 percent of the cropland, and 16.8 percent of the value of farm products (**Table 2-5**). Barge movements accounted for 9.4 percent of nationwide shipments of farm products and19.9 percent of the movements out of Illinois, Indiana, and Ohio. In 1996, nearly 15 million tons of farm products were barged on the Ohio River system.

TABLE 2-4
Coal Reserves

Description	Major Coal Field	Demonstrated Reserves 1/ (mmtons)	% of Major Coal Field	% of US
Alabama	Appalachian	4,546.6	4.2%	0.9%
Eastern Kentucky	Appalachian	12,086.2	11.2%	2.4%
Ohio	Appalachian	23,663.9	21.9%	4.7%
Pennsylvania	Appalachian	21,426.6	19.8%	4.2%
Tennessee	Appalachian	815.7	0.8%	0.2%
Virginia	Appalachian	2,202.0	2.0%	0.4%
West Virginia	Appalachian	35,397.1	32.7%	7.0%
		100,138.1	**92.6%**	**19.7%**
Illinois	Interior	105,068.9	65.8%	20.7%
Indiana	Interior	9,916.5	6.2%	2.0%
Western Kentucky	Interior	19,954.4	12.5%	3.9%
		134,939.8	**84.5%**	**26.6%**
Appalachia		**108,088.8**		
Interior		**159,611.4**		
West		**240,039.5**		
US		**507,739.6**		

1/ Demonstrated coal reserves include beds of bituminous and anthracite coals 28 inches or more thick and sub-bituminous coal 60 inches or more thick at depths up to 1000 feet. Also included are lignite seams 60 inches or more thick that can be surfaced mined.

TABLE 2-5
Cropland and Value of Production
(Million Acres and Million $)

Area	Land Area	Cropland	Value of Production
IL, IN, OH	84.7	50.9	23,974
Rest of ORB	128.4	28.4	7,843
U.S.	2,263.2	460.0	142,442
IL, IN, OH as % of U.S.	3.7	11.1	16.8

2.3.3 Water Supply

Among the nation's streams, the Ohio River is second only to the lower Mississippi in terms of volume of flow. Streams flowing out of the Appalachian Mountains and the Allegheny plateau; the Monongahela, the Allegheny, the Kanawha, the Cumberland, and the Tennessee rivers contribute the greatest flow to the Ohio. However, its vast watershed is also drained by major streams like the Muskingum, the Scioto, the Little Miami, the Kentucky, the Green and the Wabash rivers. A system of reservoirs on these streams or their tributaries insures reliable flows for navigation and municipal and industrial water supply on the Ohio and its tributaries.

2.3.4 Woodlands

Forty-three percent of the basin is classified as forestland according to the Department of Agriculture. This compares to 29 percent for the nation as a whole (**Table 2-6**). Most of the basin's forested land is confined to the Appalachian Mountains or its western foothills and upland areas, though sizeable tracts of forestland can be found in southeastern Ohio and southern Illinois. While hardwoods, especially oaks, prevail, there are sizeable stands of cultivated southern pine in the Tennessee Valley in particular. Higher-grade hardwoods are harvested for domestic and foreign manufacture of furniture, while the lower grades are used for lumber, railroad timbers, packing material, and more recently, paper manufacture. The pines are used extensively for the manufacture of paper and cardboard, primarily in the Tennessee Valley and along the Gulf Coast.

TABLE 2-6
Land Use
(Million Acres)

Land Use	U.S.	%	Basin	%
Forest Land	648	29%	91	43%
Other	1,615	71%	122	57%
Total	2,263	100%	213	100%

2.4 ECONOMY

The economic environment in the ORB is quite similar to that of the country as a whole. It includes highly diversified manufacturing complexes, urban service and trade centers, rich agricultural areas, and industries centered on the utilization of the region's abundant natural resources.

The ORB is strategically situated to supply raw materials to other regions of the country. To the east, the populous northeastern corridor bounds the ORB. To the north lie the Upper Mississippi Valley and Great Lakes region. To the south, the Ohio and Mississippi rivers tie the region to the economies of the southern Atlantic and Gulf Coast regions.

In addition to its proximity to other economic regions and markets, the ORB is linked to those places by a diverse and well-developed transportation infrastructure. The centerpiece of this infrastructure is the ORS. The Ohio and navigable portions of the Allegheny, Monongahela, Kanawha, Green, Tennessee, Cumberland, and Kentucky rivers form a web of arteries for the inexpensive movement of goods within the ORB; connecting its industries to many other local and domestic markets.

Pittsburgh area steel producers gained some measure of advantage from their ready access to water transportation. This advantage contributed to the emergence o Pittsburgh as the steel-making center of the United States for most of the 20th century. The electric power industry also found ideal conditions for growth along the Ohio and its tributaries. Chemical and metals industries (particularly aluminum) also appeared in the region because of the availability of water transportation.

The economy of the basin is diversified, but more oriented towards coal mining and manufacturing than the whole U.S. economy. Focusing on coal mining, 62,840, or 77 percent of the nationwide total number of coal mining jobs, are located in the basin states (**Table 2-7**).

TABLE 2-7
Employment by Sector - 1998
(Percentages)

Sector	Ohio Basin	U.S.
Farming	2.1	2.6
Manufacturing	18.3	14.5
Mining (Coal)	0.2	0.001
Other	79.4	82.9
Total Number	27,367,400	129,204,000

2.5 CONCLUSIONS

The basin is rich in natural resources and is served by a transportation system that has served as a catalyst for extensive economic development. In summary, the principal resources are fertile soils, extensive forests, abundant water supplies, and large deposits of coal. The area is served by all modes of transportation, but with the unique regional advantage of the Ohio River, which bisects the basin. As a result, the area has a robust and diversified economy.

SECTION 3
WATERWAY DEPENDENT INDUSTRIES

3.1 GENERAL

Waterway dependent industries are those industries that realize some advantage for locating alongside a navigable waterway system. The two major advantages are the availability of a large and reliable supply of water for use in the industrial process, and the availability of an efficient and reliable waterway transportation system for the movement of goods into or out-of the facility. The transportation advantage is the advantage of interest to this study, since locks and dam projects are sized and constructed to facilitate waterway transportation. Other location factors, including taxes, labor force, terrain, and rail and road access are also important, but are beyond the scope of this study.

The degree of reliance on waterway transportation differs among industries. Moreover, in some cases the dependency is direct, while in other cases it is indirect. For example, a new electric furnace steel mill may not use the river at all for transportation, but it may have located in the area because of the availability of low-cost electricity from a nearby generating plant that receives coal by barge. Major industrial users of the waterways are shown in **Table 3-1**.

TABLE 3-1
Major Users of Waterway Transportation and Dependency

1. High Dependence
1) Coal Mining
2) Electric Generating
3) Coke Production
4) Steel Production
5) Petrol-Chemicals
6) Construction
7) Other Lower Profile Industries
2. Low Dependence
1) Agriculture
2) Wood Products

The major users of the waterway are the coal industry and the electric generating industry (see **Table 3-2**). While it is likely that both industries would have developed even without a navigable transportation system, it is unlikely that they would have grown to the extent that they have. The reason is that waterway transportation provides a cost-advantage over other modes, which allows coal produced in the area to be competitively priced in a geographically wider market than it would be otherwise. As far back as a

hundred years ago, coal produced in the Monongahela River Basin was shipped down-river as far as Oklahoma. In contrast, no coal was delivered overland to these markets. The same is true of the electric generating industry; because of the low transportation cost of waterway shipments, and the multiple sources of coal available via waterway transportation, electric generating costs in the basin are among the lowest in the nation.[1] Electricity produced in the basin can be economically exported to high-cost production areas. Again, the size of the market and the amount of electricity generated would be less without the transportation cost savings provided by the waterway system.

TABLE 3-2
ORS Waterway Commodity Traffic, 2001

Commodity		Tons (Millions)
Coal	**Total**	**157.1**
	Steam Coal	130.7
	Metalurgical Coal	10.1
	all else	16.3
Crude Petroleum	**Total**	**0.3**
Petroleum Products	**Total**	**20.2**
Chemicals	**Total**	**10.6**
	Fertilizers	2.8
	all else	7.8
Aggregates	**Total**	**46.7**
	Sand & Gravel	18.4
	Limestone	24.6
	all else	3.7
Grains	**Total**	**18.2**
Ores & Minerals	**Total**	**6.9**
Iron & Steel	**Total**	**11.0**
	Steel Scrap	1.6
	all else	9.4
Others	**Total**	**8.9**
	Wood Products	0.6
	all else	8.3
Grand Total		**279.9**

Low-cost electricity also attracted energy-intensive industries to the region. Foremost among these are the aluminum and the steel industries, particularly the new electric furnace plants that recycle scrap into steel. The principal input of both industries is electricity, and therefore, the availability of low-cost electricity is a major consideration in location decisions.

The traditional steel industry is similar to the electric generating industry in its relation to coal and secondary processors. First, coal is the basic fuel of the industry, although the coal is pre-processed at coke plants where impurities and other undesirable characteristics are removed. The coke is then transported to raw steel producing plants where it is burned to produce the heat to separate iron from other materials. The iron is

[1] According to the U.S. Department of Energy, Energy Information Administration, average revenue per kilowatt-hour is 5.9 cents for the eight Ohio River Basin states and 6.8 cents for the entire United States. Only six states have lower average revenues than the mean average revenue for the basin states.

transformed into steel, which is itself transformed into ingots, slabs, or other shapes for shipment to plants where it is used in the construction of appliances, automobiles, and other final consumer products. The availability of coal and the efficiency of transporting it by barge to Pittsburgh were major determinants in the early development of the steel industry in the Pittsburgh area.

While coal and coal/electricity-dependent industries are the major waterway dependent industries, there are important non-coal related industries as well. The largest of these, from a tonnage standpoint, is the aggregates industry, which produces limestone, sand, and gravel. Sand and gravel move by barge from waterside quarries and dredge sites to riverside yards and ready-mix plants, and in some cases, directly to construction sites. In addition to providing low cost transportation, shipment by barge minimizes the movement of trucks through congested areas. Waterside limestone quarries and mines supply these same construction industry users and the cement, lime, and electric utility industries as well. Two other major industries in the region are the oil and chemical industries. In the case of the chemical industry, raw feedstock materials generally come from petrol-chemical complexes located along the Gulf Coast. Barge-sized allotments are the most economical and safest way to supply Ohio Basin facilities producing specialized chemical products. One barge carries the equivalent of several rail cars and being double hulled, means spills are less likely. The petroleum industry in the basin relies heavily on the ORS for its transportation needs. One reason is that asphalt and fuel oil, two industry commodities, cannot be shipped by pipeline. This makes barge transportation the most sensible, economical, and reliable mode of transportation. Petroleum refiners depend on the waterways to ship final product to major urban areas located on the river.

Agriculture is an enterprise that uses the waterway transportation system extensively to link to domestic and overseas markets and to diversify its marketing options. Grain shippers often prefer barge to alternative modes because barges not only provide transportation, but also can serve as relatively low-cost floating warehouses. The waterway system serves as the primary conduit for Midwestern grains and other agricultural products to reach growing domestic and overseas markets. From a national perspective, access to the export market, especially via the Mississippi River, is the waterway's principal effect on agriculture. In the Ohio Basin, the waterway's role is divided between connecting upper Midwestern farmers with Southeastern grain processors and poultry producers, and connecting lower Ohio Basin farmers with the Mississippi River and the Gulf Coast.

Wood-related activities include timber harvesting for export, lumber, and the processing of wood for pulp and paper mills. While a limited amount of hardwood export occurs, most forest products move in the form of pulpwood or wood chips for eventual paper product manufacture. Paper and paper product manufacturers additionally support the manufacture and delivery of salt, which is used to make chlorine and caustic soda—direct inputs to paper and paper product manufacture. Chlor-alkali plants manufacture the critical chlorine and caustic soda inputs, and rely on waterborne shipments of salt, primarily from salt mines along the Gulf Coast. Chlor-alkali plants are often located close to paper plants, allowing chlorine shipments by pipeline and minimizing any transportation costs or risks.

There are a number of other water-dependent industries along the waterway that depend on the waterway more for water supply but also use the waterway as an optional transportation mode, and for an occasional barge shipment. These types of plants include mineral processing plants such as zinc, nickel, and aluminum plants. Other facilities are highly dependent on the waterway transportation system, but may ship modest quantities on the system. These facilities would include the intermodal ports that provide a wide variety of shipping options to a wide variety of industries and cargoes in order to survive.

3.2 HIGH-LEVEL DEPENDENCE

3.2.1 Coal Mining

The markets for coal are electric generating plants, coke plants, other industrial plants such as cement, and export. As a consumer of coal, the electric generating industry dwarfs the other sectors, consuming 911 million tons a year or 87 percent of the one billion tons of coal produced in the U.S. every year. The Ohio River Basin is an important production region and proximity to waterways provides a cost advantage over production in other regions of the country. A listing of the largest mines located in counties along the Ohio, Monongahela, Green, Kanawha, and Big Sandy rivers is provided in **Table 3-3**, along with production numbers for 2001. Over ten percent of national production came from these large ORB mines in 2001.

Coal production in the Appalachian region of the basin was up in 2001. Most of the increase was accounted for by the two major coal producing states in the region—Eastern Kentucky and West Virginia even though West Virginia coal production was constrained by a lawsuit in Federal court involving mountaintop removal and valley fills. Eastern Kentucky's production rose and Pennsylvania produced about the same as in the previous year. Ohio, the fourth largest coal producing state in the Appalachian region also increased coal production. Alabama and Tennessee had slight increases in their coal production in 2001. The Interior region increased coal production in 2001 as well. Reflecting the opening of three new mines in 2001 in Indiana, as well as the first full year of production by four other coal mines in the state, the greatest increase in tonnage in the Interior region was registered by Indiana. Coal production in Western Kentucky dropped in 2001, while production in Illinois increased marginally. **Table 3-4** shows the number of ORB coal mines, by state, and the overall decrease in their number since 1996.

3.2.2 Electric Generation

The electric generating industry is one of the little noticed, but key industries, in the nation's economy. Its importance is little appreciated until we are without power, and find ourselves groping in the dark for candles and throwing out food from our refrigerators. The electric power industry is currently undergoing radical change. The industry has been dominated by monopolistic and tightly regulated utilities. Technological innovation and consumer demand for choice provides an impetus for the deregulation of electric utilities. Deregulation is slowly introducing competition into the generation and wholesale selling of electricity.

TABLE 3-3
Major ORB Waterside Coal Mines, 2001

State	County	Company	Mine	Kilotons
IL	Gallatin	Coal Miners, Inc.	Eagle Valley Mine	1,316
		State Total		**1,316**
IN	Warrick	Peabody Coal Co.	Lynnville Surf & Prep Plant	999
IN	Warrick	Peabody Coal Co.	Squaw Creek & Prep Plant	407
IN		**State Total**		**1,407**
KY	Union	Peabody Coal Co.	Camp No. 1	1,424
KY	Union	Peabody Coal Co.	Camp No. 11	1,541
KY	Union	Island Creek Coal Co.	Ohio #11 Undrgrd Mine	667
		State Total		3,632
OH	Belmont	Ohio Valley Coal Co.	Powhatan No. 6 & Prep Plant	4,611
OH	Meigs	Southern Ohio Coal Co.	Meigs 31 & Prep Plant (Ms-293)	2,165
OH	Meigs	Southern Ohio Coal Co.	Meigs No. 2 (Ms-294)	2,120
OH	Monroe	Quarto Mining Co.	Powhatan #4 Mine & Prep	448
		State Total		**9,344**
PA	Greene	Consolidation Coal Co.	Bailey No. 1 mine	10,327
PA	Greene	Cyprus Cumberland Resources	Cumberland Mine & Prep Plant	6,655
PA	Greene	Consolidation Coal Co.	Dilworth Mine (NWV Region)	5,034
PA	Greene	Enlow Fork Mining Co.	Enlow Fork Mine	10,326
PA	Greene	Cyprus Emerald Resources Corp.	Emerald No. 1 mine & Prep	6,738
PA	Greene	New Warrick Mining Co.	Warwick #3 Undrgrd & Prep Plant	
PA	Somerset	PBS Coal Mining, Inc.	PBS No. 1 Surface Mine	
PA	Washington	Maple Creek Mining, Inc.	Maple Creek	2,642
PA	Washington	MonView Mining, Inc.	Mathies Mine & Prep Plant	1,280
PA	Washington	Eighty Four Mining Co.	Mine No. 84	3,595
		State Total		**46,597**
WV	Barbour	Phillipi Development, Inc.	Sentinel Mi 1583/2587	
WV	Brooke	Windsor Coal Co.	Windsor Mine & Prep Plant	
WV	Harrison	Consolidation Coal Co.	Robinson Run #95 D-4786 & Prep	4,910
WV	Marion	Consolidation Coal Co.	Loveridge #22 D-402 & Prep	
WV	Marshall	McElroy Coal Co.	McElroy Mi 5443	
WV	Marshall	Consolidation Coal Co.	Shoemaker Mi 4791	4,088
WV	Monongalia	Consolidation Coal Co.	Blacksville No. 2 Mine & Prep	
WV	Monongalia	Eastern Associated Coal Corp.	Federal No. 2 & Prep	4,878
WV	Monongalia	Consolidation Coal Co.	Humphrey No. 7 D-415 & Prep	
WV	Monongalia	Patriot Mining Co., Inc.	Osage & Bethel	
WV	Fayette	Cyprus Kanawha Corp.	Armstrong Creek	
WV	Kanawha	Cannelton Industries, Inc.	Stockton Mine	
WV	Kanawha	Dunn Coal & Dock	No. 1	
WV	Wayne	Pen Coal Corp.	Kiah Creek Surface Mine	
WV	Wayne	Rockspring Development Co.	Camp Creek Mine	
		State Total		**13,876**
		Grand Total		**72,540**

Source: EIA Annual Coal Report, Major U.S. Coal Mines, 2001

TABLE 3-4
Number of ORB Coal Mines, 1996-2001

ORB State	1996	1997	1998	1999	2000	2001	Av. Ann. Pct. Chnge. 1996-01
Alabama	53	51	53	47	42	40	-5.47%
Indiana	37	39	41	34	30	33	-2.26%
Illinois	31	28	24	23	18	20	-8.39%
Kentucky	544	529	482	458	408	467	-3.01%
Ohio	99	81	83	79	60	60	-9.53%
Pennsylvania	402	403	375	339	307	266	-7.93%
Tennessee	26	27	27	24	20	23	-2.42%
West Virginia	386	349	346	306	297	304	-4.66%
U.S. Total	1,903	1,828	1,726	1,591	1,453	1,512	-4.50%

The electric power industry involves the generation, transmission, and distribution of electricity. Fossil fuels are the most widely used fuel for electricity generation. Coal is the most widely used fossil fuel in the United States, and particularly in the ORB. In fact, the ORB is the U.S. region most dependent upon coal for electric power generation. Fossil fuels are transported to generating plants by rail, river barge, truck, conveyor, and pipeline with a modal share of 15 percent, 78 percent, 5 percent and 2 percent resprctively. Electricity is transmitted from generating plants to consumers by wire. The electric power industry is the largest user of the ORS. In 2001, over 130 million tons of coal and 2.3 million tons of lime were barged to electricity generating plants. These movements represent almost fifty percent of total tonnage transported on the ORS.

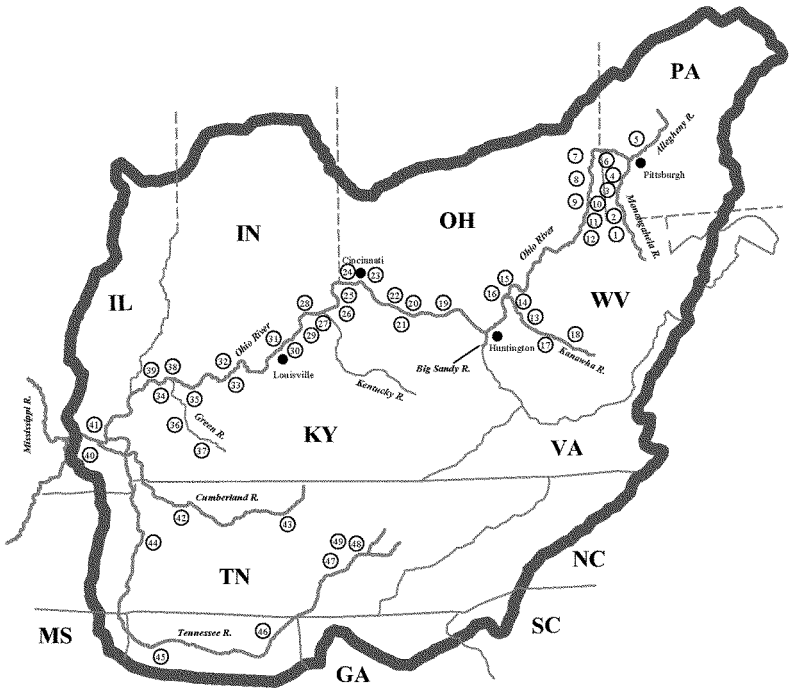
The electricity industry is an important consumer, as well as a key producer, in the economy. The industry consumes about 87 percent of the over 1 billion tons of coal produced in the country (**Table 3-5**). Of this amount, about 14 percent or nearly 120 million tons moves on the Ohio River system to waterside power plants. The tonnage accounts for about 1 of every 2 tons shipped on the system. **Figure 3-1** shows the location of the coal-fired power plants along the river system and **Table 3-6** shows the capacity and coal-burn of each plant. The waterside power plants shown in Figure 3-1 and listed in Table 3-6 receive over 78 percent of its coal by barge

TABLE 3-5
U.S. Coal Production and Consumption, 1999-2004
(Million Tons)

Item	1999	2000	2001	2002	2003	2004
Production by Region						
Appalachian	425.6	419.4	431.2	396.2	376.0	389.3
Interior	162.5	143.5	146.9	146.6	146.0	145.8
Western	512.3	510.7	547.9	550.4	548.7	575.2
Total	1,100.4	1,073.6	1,126.0	1,093.2	1,070.7	1,110.3
Consumption by Sector						
Electric Power	940.9	985.8	965.1	977.5	1,005.1	1,015.1
Coke Plants	28.1	28.9	26.1	23.7	24.2	23.7
Other Industrial Plants	64.7	65.2	65.3	60.7	61.3	61.2
Combined Heat and Power (CHP)	27.7	28.0	26.4	26.2	24.8	28.0
Non-CHP	37.0	37.2	38.8	34.5	36.4	33.2
Residential	0.6	0.5	0.5	0.5	0.5	0.5
Commercial	4.3	3.7	3.9	4.0	3.8	3.8
Total	1,103.3	1,149.3	1,126.1	1,127.1	1,156.1	1,165.5

Source: U.S. Energy Information Administration, *U.S. Coal Supply and Demand: 2004 Review*, table 1.
http://www.eia.doe.gov/cneaf/coal/page/special/feature04.pdf

FIGURE 3-1
Coal-Fired Power Plants along the ORS



Code	Plant	Code	Plant	Code	Plant
1	Fort Martin	18	Kanawha Rv	35	Wilson
2	Hatfield	19	Killen	36	Green River
3	Mitchell	20	Stuart	37	Paradise
4	Elrama	21	Spurlock	38	Warrick
5	Cheswick	22	Zimmer	39	Brown
6	Mansfield	23	Beckjord	40	Shawnee
7	Sammis	24	Miami Fort	41	Joppa
8	Cardinal	25	Tanners Crk	42	Cumberland
9	Burger	26	East Bend	43	Gallatin
10	Kammer	27	Ghent	44	Johnsonville
11	Mitchell	28	Clifty Crk	45	Colbert
12	Pleasants	29	Trimble	46	Widows Crk
13	Mountaineer	30	Mill Crk	47	Watts Bar
14	Sporn	31	Gallagher	48	Kingston
15	Gavin	32	Rockport	49	Bull Run
16	Kyger Creek	33	Coleman		
17	Amos	34	Reid		

TABLE 3-6
Waterside Electric Generating Plants

Name	Milepoint*	River	State	Electricity Generation (MWh)	Coal Consumption (Ktons)
Amos	39.7	Kanawha	WV	15,332,459	5,891.27
Beckjord	452.9	Ohio	OH	5,996,393	2,581.65
Brown	0.0	Ohio	IN	2,463,116	1,148.86
Bull Run	47.6	Clinch	TN	5,005,472	1,781.99
Burger	102.3	Ohio	OH	2,083,114	852.97
Cardinal	76.2	Ohio	OH	9,318,453	3,751.46
Cheswick	15.4	Allegheny	PA	3,075,764	1,231.58
Clifty Crk	559.6	Ohio	IN	9,731,944	4,909.20
Colbert	245.3	Tennessee	AL	7,700,791	3,224.20
Coleman	728.5	Ohio	KY	3,028,554	1,408.85
Cumberland	103.4	Cumberland	TN	16,172,326	6,867.29
East Bend	511.0	Ohio	KY	3,911,592	1,614.75
Elrama	25.1	Monongahela	PA	2,557,114	1,171.99
Fort Martin	92.0	Monongahela	WV	5,338,113	2,037.71
Gallagher	610.1	Ohio	IN	2,655,158	1,158.53
Gallatin	244.1	Cumberland	TN	6,587,951	2,574.40
Gavin	258.5	Ohio	WV	16,861,183	7,367.77
Ghent	535.8	Ohio	KY	11,916,391	4,995.45
Green River	81.5	Green	KY	708,250	354.78
Hatfield	79.0	Monongahela	PA	9,028,465	3,439.43
Johnsonville	99.6	Tennessee	TN	7,653,279	3,687.73
Joppa	952.3	Ohio	IL	7,873,723	4,833.63
Kammer	111.1	Ohio	WV	4,529,114	1,786.55
Kanawha Rv	78.3	Kanawha	WV	1,920,846	763.62
Killen	390.6	Ohio	OH	4,274,313	1,750.61
Kingston	2.6	Clinch	TN	9,782,767	3,851.90
Kyger Creek	259.6	Ohio	OH	7,739,685	2,924.82
Mansfield	33.1	Ohio	PA	14,556,736	5,944.03
Miami Fort	490.1	Ohio	OH	7,474,143	3,049.96
Mill Crk	626.5	Ohio	KY	8,765,110	3,995.44
Mitchell	112.3	Ohio	WV	8,296,523	3,213.29
Mitchell	29.5	Monongahela	PA	788,777	338.73
Mountaineer	243.4	Ohio	WV	7,363,098	2,756.07
Paradise	99.5	Green	KY	14,335,401	6,117.32
Pleasants	160.5	Ohio	WV	8,232,933	3,454.05
Reid	41.2	Green	KY	85,973	45.20
Rockport	744.7	Ohio	IN	16,790,788	10,100.27
Sammis	52.9	Ohio	OH	13,858,788	5,800.34
Shawnee	946.0	Ohio	KY	7,923,517	3,572.54
Sporn	241.6	Ohio	WV	5,900,556	2,343.48
Spurlock	414.1	Ohio	KY	5,453,418	2,177.98
Stuart	404.5	Ohio	OH	13,860,448	5,770.66
Tanners Crk	494.0	Ohio	IN	4,936,598	1,939.41
Trimble	0.0	Ohio	KY	3,016,348	1,419.80
Warrick	774.0	Ohio	IN	1,149,274	538.57
Watts Bar	529.1	Tennessee	TN	-2,756	0.00
Widows Crk	407.3	Tennessee	AL	8,766,790	3,985.68
Wilson	74.0	Green	KY	3,045,944	1,380.21
Zimmer	0.0	Ohio	OH	10,266,343	4,042.93

* Mile points indicate distance from source for the Ohio River and distance from the mouth for tributaries.

3.2.3 Coke Production

Coal is pre-processed in coke plants to remove impurities and other undesirable characteristics prior to use in a traditional steel plant. The process is accomplished in a series of ovens, which effectively bake out the impurities. By-products of the process include gases, which are often transported to adjacent plants for use as inputs in chemical processing. The coke itself is transported to steel plants where it is used to process iron ore into iron and thence into steel. A listing of the waterside coke plants in the basin is provided in **Table 3-7**. The number of coke plants within the basin and the country as a whole has declined significantly over the past 20 years, such that the remaining plants are generally considered to be internationally competitive. The coke plant at Clairton is the largest in the country; its output goes to USX steel plants throughout the country.

TABLE 3-7
Waterside Coke Plants

Name	Milepoint	River	State
AK Steel	320.0	Ohio	KY
New Boston Coke Corp.	351.0	Ohio	OH
Koppers Industries	38.0	Monongahela	PA
Shenango, Inc.	8.0	Ohio	PA
USX Clairton	20.1	Monongahela	PA
Wheeling-Pittsburgh Steel	69.0	Ohio	WV

3.2.4 Steel Production

Iron and steel are two of the most important materials in an industrial economy. Steel is used in construction, automotive assembly, and appliances. Regionally, steel production has declined precipitously since the early 1980s, when most of the old integrated plants in the Pittsburgh area were closed and demolished. The construction or expansion of electric arc furnaces led to a resurgence of steel production in the 1990s. New mini-mills have sprung up on the Ohio and Tennessee rivers. This growth was accompanied by continuing expansion of the automobile industry in the Ohio River Basin. The industry remains a key generator of barge transportation. A list of the major waterside steel plants in the basin is provided in **Table 3-8**.

TABLE 3-8
Major Waterside Steel Plants

Name	Milepoint	River	State	Type	Capacity (mmtons)
AK Steel	320.0	Ohio	KY	BOF	2
Kentucky Electric	n/a	Ohio	KY	Electric	n/a
Gallatin Steel	536.0	Ohio	KY	Electric	1.0
Newport Steel	2.0	Licking	KY	Electric	0.7
Steel of West Virginia	307.0	Ohio	WV	Electric	0.3
Weirton Steel	63.0	Ohio	WV	BOF	3.0
Wheeling	69.0	Ohio	WV	BOF	2.4
USX	11.0	Monongahela	PA	BOF	2.9

3.2.5 Petrol-Chemicals

The petroleum industry generates large volumes of traffic on the inland waterways in the form of refined petroleum product outputs and, to a much lesser extent, crude oil inputs. The chemical industry is comprised of basic chemical building blocks (low-value bulk) and final products (primarily high-value except fertilizer which is also bulk). This means that only basic chemicals and fertilizer are candidates for barge traffic.

The heaviest concentration of chemical companies is on the Kanawha River and on the Ohio River between Marietta and Portsmouth, Ohio. One medium-sized refinery, located in Ashland, Kentucky, is located on this same stretch of river. Other petrol-chemical facilities (**Table 3-9**) ranging from plants to tank farms are located throughout the basin.

TABLE 3-9
Waterside Petrol-Chemical Facilities

Name	Milepoint	River	State	Type
Amoco Chemicals Corp.	299	Tennessee	AL	Petro
Aristech Chemical Co.	337	Ohio	OH	Chem
Ashland Petroleum Co.	317	Ohio	WV	Petro
Ashland Petroleum Co. Midland	35	Ohio	PA	Petro
B.F. Goodrich Co.	17	Tennessee	KY	Chem
Chevron Chemical Co.	177	Ohio	OH	Chem
Dow Corning	541	Ohio	KY	Chem
Dupont	68	Kanawha	WV	Chem
Koppers Industries, Inc.	70	Ohio	WV	Chem
Monsanto Co.	302	Tennessee	AL	Chem
Nova Chemicals, Inc.	30	Ohio	PA	Chem
PPG Industries, Inc.	120	Ohio	WV	Chem
Quaker State Oil	47	Ohio	WV	Petro
Union Carbide Corp.	55	Kanawha	WV	Chem

3.2.6 Construction

Construction activities are important markets for a wide variety of industries. Waterway transportation is used to move bulk construction materials: crushed stone, gravel, sand, cement, concrete, asphalt, and structural steel. While movements of these materials are directly affected by building construction, heavy construction is responsible for the largest waterway flows. Heavy construction projects are major consumers of stone, with large waterway improvement projects being especially important to waterside aggregate producers.

Construction is the largest consumer of raw materials of any industry in the country. The principal raw materials are stone, sand and gravel, steel, and wood products. Most waterborne construction material is crushed stone, sand and gravel used in making concrete. Typically, barges move the aggregate from quarry or dredge site to ready mix plants or stone yards located in or near urban areas. The waterway leg allows the shipper to bypass populated areas with their large bulk flows, while still getting product where they need it. Trucks are generally used to transport product to the work site, though some large construction projects receive aggregate by barge directly.

3.2.7 Other Lower Profile Industries

The list of industries and facilities dependent on the waterway system is extensive, and only the major ones are listed above. Some of the "lower profile" industries are highly dependent on the waterways, but involve lower volumes due to the nature of the business and/or the value of the product.

3.2.7.1 Steel Recycling

The steel scrap business involves the acquisition of junked autos, appliances, industrial trimmings, and other items and processing these items into prime scrap. Processing involves the removal of non-steel components from the junked items. The prime scrap is then sold to steel plants which either blend the scrap with iron to produce steel, or which make steel entirely from melting scrap in an electric furnace. The scrap is sold to both domestic and foreign companies.

Scrap is the major input to electric arc furnaces. Much of the scrap used is generated by the steel production process (home scrap) and by metal processors and users (purchased scrap). Mini-mills have traditionally located near their markets and a source of scrap (major urban areas). Scrap is generally moved by rail and to a lesser extent by truck. Some mini-mills have located near rivers to receive scrap by barge.

The U.S. steel industry consumed over 63 million tons of scrap in producing over 99 million tons in 2001. Because of the low value and broad and dispersed sources of scrap, many scrap companies choose to locate along the river system. Prime scrap is generally railed to domestic mills and barged to New Orleans for foreign mills. Shipments of scrap on the Ohio River system totaled 1.6 million tons in 2001.

3.2.7.2 Synthetic Fuel Production

Decades of mining have resulted in millions of tons of waste materials that are aesthetically and environmentally detrimental. Efforts are underway to economically cleanup up these piles of wastes. One effort involves the conversion of part of the wastes into useful products, such as synthetic fuels. The synthetic fuels, referred to as briquettes, are reusable by either the utility industry or the steel industry, depending on the grade of the briquettes. Again, the businesses prefer a waterside site since the wastes come from multiple origins, which are often on or near the water.

3.2.7.3 Gypsum Recycling

Synthetic gypsum, which is a byproduct of flue gas desulfurization, a process that removes SO_2 from coal-fired emissions, is used to produce wallboards for construction industry. Again, the businesses prefer a waterside site since the wastes come from multiple origins, which are often on or near the water.

3.2.7.4 Aluminum and Zinc Production

The principal minerals refined at basin plants are aluminum bauxite and zinc oxide. The Ohio River Basin is home to the second largest concentration of aluminum plants in the U.S. Aluminum plants are located in the region because of low-cost electricity afforded by the region's coal and hydroelectric power plants. While most zinc used in the U.S. is imported, zinc ores are processed in the basin because of localized deposits on the Tennessee River. The ore is barged to refiners on the Cumberland, McClellan-Kerr-Arkansas, and Ohio rivers.

3.2.7.5 Cement and Lime Production

Rich, vast deposits of limestone supply more than just crushed stone for heavy construction. These deposits also support cement and lime production, which is centered in the southern and western portion of the basin. Numerous cement kilns in Ohio, Indiana, Kentucky, Illinois, Missouri, Tennessee, and Alabama receive limestone and ship cement by barge. Six lime kilns located in Kentucky, Missouri, and Tennessee rely upon waterborne limestone, and in turn ship lime to the region's steel makers, paper plants, and electric utilities.

3.3 LOWER LEVEL DEPENDENCE

Farming is dependent on waterway transportation to the extent that waterway transportation allows farm products to be competitive in distant markets. This, in turn, affects the farmer's selection of what to grow since the market for high valued products expands with distance. The most distant markets are overseas, while closer markets are generally food-processing plants. A listing of facilities used to load or unload barges of farm products is provided in **Table 3-10**.

TABLE 3-10
Waterside Facilities for Farm Products

Name	Milepoint	River	State
A.E. Staley	592	Tennessee	TN
Aurora Terminal Co., Inc.	496	Ohio	IN
Bunge Corp.	980	Ohio	IL
Cargill, Inc.	793	Ohio	IN
Cargill, Inc.	479	Ohio	OH
Consolidated Grain & Barge	597	Ohio	IN
Consolidated Grain & Barge	475	Ohio	OH
Continental Grain Co.	831	Ohio	IN
Garnac Grain Co.	780	Ohio	IN
Hopkinsville Elevator Co.	123	Cumberland	TN
Indiana Port Commission	831	Ohio	IN
Livingston Point River Terminal	4	Tennessee	KY
Owensboro Grain Co.	756	Ohio	KY
Peavey Co.	805	Ohio	KY
Wabash Elevator Co.	843	Ohio	KY

Paper and wood product production are major activities in the southern part of the basin, particularly along the Tennessee River. Shipments of products to and from these plants are of significant local importance, although minor in terms of overall Ohio River System tonnage.

3.4 CONCLUSION

All industries in the ORB are to some degree dependent on the existence of an efficient and reliable navigation system. This includes industries that may never have shipped via barge and have no plans for doing so. In fact, some of the industries most highly dependent on waterway transportation do not ship on the rivers, but depend on the cost-savings that it provides to their suppliers, making them both more competitive. The waterway transportation system allows for lower transportation costs, and therefore lower delivered costs of basic raw materials, most importantly coal, ores, chemicals and stone, to secondary producers of goods such as electricity, coke, specialty chemicals, and construction materials. In turn, these industries generally spawn tertiary producers of items like steel coils and slabs, aluminum, and paper products, which are then used in factories that produce final consumer goods such as automobiles, appliances, utensils, packaging, and food products.

Section 6 of this appendix, Historic and Projected Traffic, documents the steady growth of waterway traffic over the past 63 years (**Table 3-11**) and provides indisputable evidence of basin shipper's dependence on the ORS. With the exception of export demand for coal and grain, the preponderance of commodities shipped on the waterway are *relatively unaffected* by changes in waterway prices. Both raw material production facilities and the downstream production facilities they supply represent major capital investments. More importantly for this study, these investments represent a long-term commitment to the waterway, a commitment likely unwavering over a 20- to 30-year horizon. There are a number of reasons for this. Alternative development sites are

extremely limited for quarries, power plants, steel mills, coal mines, chemical plants, petroleum refineries, and paper mills. Some of these facilities are legacies of job-rich economic development now considered undesirable in other areas of the country. Also, in many instances, production is geographically circumscribed, as is the case with stone, wood products, and coal. Consuming plants may also require specifications unique to a particular ORB resource. This is particularly true with respect to the requirements of some utility plants for certain grades of coal for their boilers and chemical properties of limestone for their flue-gas de-sulfurization units. Finally, transportation options are often extremely limited. Large machines and steel fabrications, like electricity generators, often can move no other way than by water, and high volume bulk commodity shipments can be moved in a less disruptive fashion past major urban concentrations when they use the waterways. Limited alternatives for locating new plants, substituting product from other areas, and arranging alternative transportation act to make long run demands for waterway service in the ORB relatively stable.

TABLE 3-11
Historic ORS and Mainstem Traffic
(Million Tons)

	Ohio River		Mainstem
Year	Mainstem	System	% Total
1940	29.5	51.2	57.6%
1950	48.6	66.1	73.5%
1960	79.5	105.3	75.5%
1970	129.6	163.9	79.1%
1980	174.9	200.5	87.2%
1990	225.7	257.8	87.5%
2000	236.3	271.7	87.0%
2003	228.8	259.8	88.1%
Avg. Annual			
1940-2003	3.3%	2.6%	
1990-2003	0.1%	0.1%	

Source: WCSC data.

SECTION 4
OHIO RIVER NAVIGATION SYSTEM

4.1 INTRODUCTION

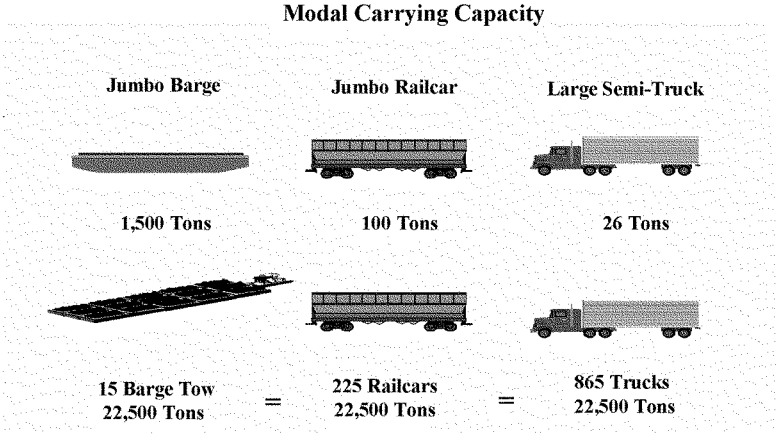
The Ohio River navigation system (ORS) is a major portion of the nation's inland navigation system, providing commercial navigation in the eastern one-third of the country. The ORS consists of more than 2,600 miles of commercially navigable waterways. It includes the Ohio River and the navigable portions of the Allegheny, Monongahela, Kanawha, Big Sandy, Green, Tennessee, Cumberland, and Kentucky rivers. The Ohio River serves as a collector of system traffic for distribution to points within and outside the Ohio basin while the tributary streams serve major mining areas and industrial concentrations within the Basin. Through interconnections with the Mississippi River and its tributaries, ORS traffic has access to Midwestern states and deep-draft ports on the Great Lakes and Gulf Coast. Year–round navigation on the Ohio River is provided by a system of 20 locks and dams and annual maintenance dredging.

Tows moving on the ORS system are configured to operate as efficiently as possible along each waterway segment. Lock size and channel dimensions are critical in limiting the most efficient tow configuration. Currently, the Ohio River fleet consists mostly of jumbo barges. A typical Ohio River tow is a 3,500 horsepower towboat moving 15 barges, while tows for tributaries are smaller, due to channel and lock restrictions.

Barge transportation is an energy efficient mode for carrying large quantities of bulk commodities. A typical barge can carry as much coal or grain as 15 rail cars for about the same energy per ton-mile. On certain river segments, river efficiency is much greater than rail due to the back haul opportunities barging provides. **Figure 4-1** compares the average carrying capacity for jumbo barges, railcars, and large semi-tractor trailers. The figure shows that a typical Ohio River tow carrying 22,500 tons is the equivalent of 225 railcars (2.25 unit trains) and 865 trucks.

The study area includes the mainstem Ohio River, which extends from the junction of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania, to near Cairo, Illinois where the Ohio joins the Mississippi River. This area includes 981 miles of commercially navigable channel and a total drainage area of 204,000 square miles. Year-round navigation is provided by a system of 20 locks and dams (see **Figure 4-2)** and annual maintenance dredging. The drainage area encompasses all or portions of fourteen states: Alabama, Georgia, Kentucky, Indiana, Illinois, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The navigable tributary streams to the Ohio River are not part of this draft report.

Figure 4-1
Modal Carrying Capacity



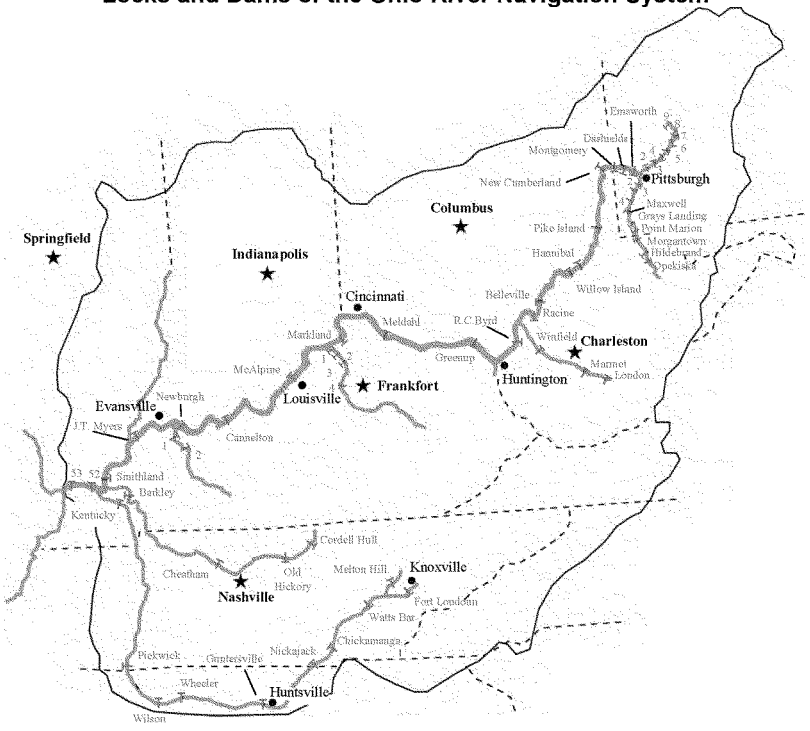
4.2 HISTORY OF DEVELOPMENT

Federal involvement in improving the Ohio River for commercial navigation began in 1824, when Congress directed the Corps to find a method for removing sandbars and snags. In 1906, the Rivers and Harbors Board recommended construction of 54 locks and dams providing a nine-foot channel for the entire length of the Ohio River. This plan, which called for 600-foot long lock chambers, was completed by the Corps between 1910 and 1929.

Once canalization was completed, the waterway spurred economic growth and assisted the rapid nationwide mobilization during World War II. Sustained post-war expansion of the national economy increased the use of all types of commodities carried on the river. This rapid growth in traffic exceeded the government's ability to increase lock capacity and by the 1950s serious delay problems had become obvious. The original 600-foot lock chambers built during the days of steamboats and small wooden barges were obsolete and could not handle modern tows (flotillas of bigger, steel barges pushed by diesel powered boats) in a single lockage.

FIGURE 4-2

Locks and Dams of the Ohio River Navigation System



4.3 RECENT LOCKS AND DAM IMPROVEMENTS

Diesel towboats and the new, larger barges brought increased efficiency to the movement of the energy, construction, and food products demanded by a world newly re-constructed following WW II. These efficiencies, however, could not be fully realized because the ORS remained a system designed to accommodate the transportation technology of the previous century. Lock chambers were small, typically with a main lock chamber 600 by 110 feet and an auxiliary lock chamber 360 by 56 feet, and because wicket dams were low-lift structures, the projects were relatively close together. As a result, plans were formulated in the 1950s to modernize the navigation system. The plans called for the replacement of the many low-lift structures with fewer high-lift structures and larger locks. The modernized structures provide higher-lift dams with longer pool-reaches between projects, and larger lock dimensions. The modernization program envisioned 19 modern high-lift projects and began in 1954 with construction of Greenup Locks and Dam with a 30-foot lift, a 1200-foot by 110-foot main

chamber, and a 600-foot by 110-foot auxiliary chamber. The specifications for the existing 20 mainstem lock and dam projects are listed in **Table 4-1**.

TABLE 4-1
Ohio River Lock Specifications

Lock & Dam	River Mile	Year Operational			Year Rehabilitated			Chamber Sizes	
Project Name	(downstream of Pittsburgh)	Main	Aux.	Dam	Main	Aux.	Dam	Main	Aux.
Emsworth	6.2	1921	1921	1922	1984	1984	1984	600 X 110	360 X 56
Dashields	13.3	1929	1929	1929	1990	1990	1990	600 X 110	360 X 56
Montgomery	31.7	1936	1936	1936	1989	1989	1989	600 X 110	360 X 56
N. Cumberland	54.4	1956	1959	1961				1200 X 110	600 X 110
Pike Island	84.2	1963	1963	1965				1200 X 110	600 X 110
Hannibal	126.4	1972	1972	1975				1200 X 110	600 X 110
Willow Island	162.4	1972	1972	1973				1200 X 110	600 X 110
Belleville	203.9	1968	1968	1969				1200 X 110	600 X 110
Racine	237.5	1967	1967	1970				1200 X 110	600 X 110
R.C. Byrd	279.2	1993	1993	1937			2000+	1200 X 110	600 X 110
Greenup	341.0	1959	1959	1962				1200 X 110	600 X 110
Meldahl	436.2	1962	1962	1964				1200 X 110	600 X 110
Markland	531.5	1959	1959	1964				1200 X 110	600 X 110
McAlpine	606.8	1961	1921	1964		1965		1200 X 110	1200 X 110 a
Cannelton	720.7	1971	1971	1971				1200 X 110	600 X 110
Newburgh	776.1	1975	1975	1975				1200 X 110	600 X 110
J.T. Myers	846.0	1975	1975	1975				1200 X 110	600 X 110
Smithland	918.5	1979	1979	1979				1200 X 110	1200 X 110
L&D No. 52	938.9	1969	1928	1929		1983	1984	1200 X 110	600 X110 b
L&D No. 53	962.6	1980	1929	1929		1982	1984	1200 X 110	600 X 110 b

a. The new McAlpine 1200' x 110' chamber became operational in 2009

b. Olmsted L/D (now under construction near L/D 53), will replace both L/Ds 52 and 53

b. Olmsted L/D will have 2 identical 1200' x 110' chambers

The modernization program continues today with improvement of Robert C. Byrd L/D located upstream of Huntington, West Virginia; Olmsted L/D on the lower Ohio River; and McAlpine L/D located near Louisville, Kentucky. In January 1993, the new Robert C. Byrd locks, measuring 1200 by 110 feet and 600 by 110 feet, became operational -- replacing the small and outdated locks at Gallipolis, Ohio; major rehabilitation of the dam was completed in September 2000. The new Olmsted L/D project at river mile 964.4 is currently under construction. The project, which will provide a modern structure to replace old L/D 52 and L/D 53, consists of twin 1200 by 110-foot locks and a new dam with submersible gates to allow tow passage over the dam during higher flow conditions. Construction was initiated in 1993 and this study assumes Olmsted online. With completion of Olmsted, the Ohio River mainstem will be reduced from 20 to 19 lock and dam structures. The Water Resources Development Act of 1990 authorized improvement of McAlpine L/D at river mile 606.8. The project is currently under construction and will replace the old 600-foot auxiliary lock with a new 1200-foot chamber -- providing this site with twin 1200 by 110-foot locks. This study assumes twin1200-foot chambers at McAlpine.

4.4 CURRENT STATE OF THE WATERWAY

The mainstem Ohio River is currently a large canalized river consisting of 20 pools formed by 20 lock and dam structures. There will be 19 pools and 19 locks and dam structures after completion of Olmsted L/D in 2010, which replaces L/Ds 52 and 53. The current profile of the Ohio River mainstem is described in **Figure 4-3**.

The current geometry of the river, as improved by the higher pool levels of the modernized dam system, generally provides for safe navigation of commercial tows as long as they are no more than 1200 feet long and 108 feet wide. A typical Ohio River jumbo-hopper-barge tow consists of fifteen 195 by 35-foot barges, plus a towboat of varying dimensions, resulting in a tow of about 1170 feet by 105 feet. Occasionally, tows on the lowermost reaches of the Ohio, below Smithland L/D, operate in a double-wide configuration of 30 barges (5 long and 6 wide), typical of the larger tows on the lower Mississippi River. During winter months, these unusually wide tows can navigate over the navigable wickets of Dams 52 and 53 (and after 2010 the wickets at the new Olmsted Dam). Such tows cannot navigate these reaches during the dryer months, when they must use the locks at L/D 52 and 53.

In terms of age and operating characteristics, the lock and dam facilities may be classified into 3 broad groups:

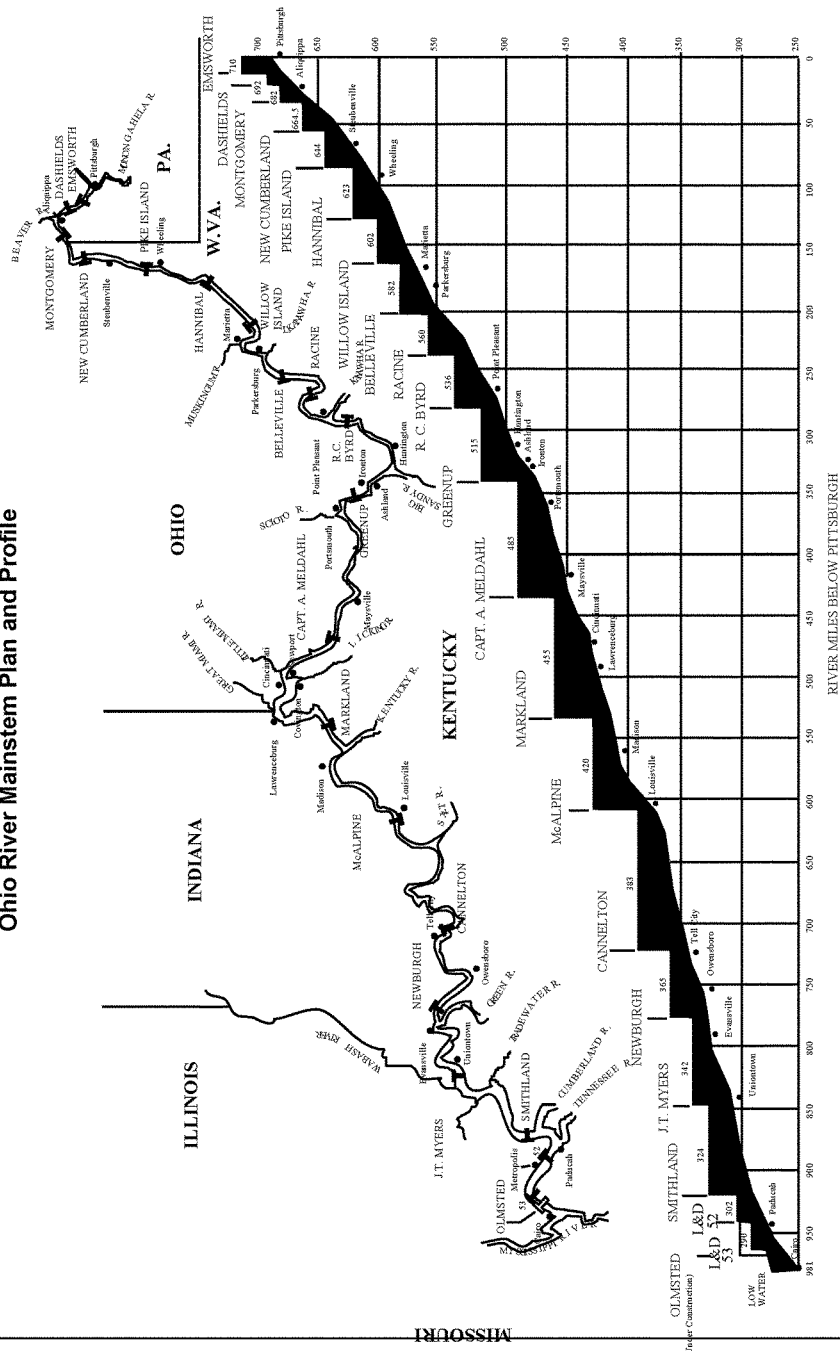
- The 60+ year old three upper most locks and dams are Emsworth, Dashshields, and Montgomery (EDM) just downstream of Pittsburgh PA. These three locks and dams each have one 600 by 110-foot main chamber and a 380 by 56-foot auxiliary chamber. Fifteen-barge tows must double cut to negotiate the main chambers, and must break apart up to 15 times to negotiate the small auxiliary chambers[1]. The condition of these old structures and the inefficiently-small lock sizes, are major concerns.

- The 13 modernized lock and dam structures constructed between 1954 and 1979 plus R.C. Byrd L/D (completed in 1993) include all the contiguous locks from New Cumberland downstream to J.T.Myers, a distance of 791.6 miles. Each of these locks has a 1200 by 110-foot main lock chamber and a 600 by 110-foot auxiliary chamber. The 1200-foot main chamber allows 15-barge tows to lock through in a single operation, while smaller vessels usually use the auxiliary chambers. These locks and dams are spaced about 60 miles apart. They replaced a series of 50 old lower-lift structures built around the turn of the century.

- Locks which have or soon will have dual, side-by-side 1200 by 110-foot chambers include Smithland L/D (placed in operation in 1980), and McAlpine and Olmsted L/Ds.

[1] Tow-size is restricted to 5-barges (5-cut tows) at EDM during main chamber closures.

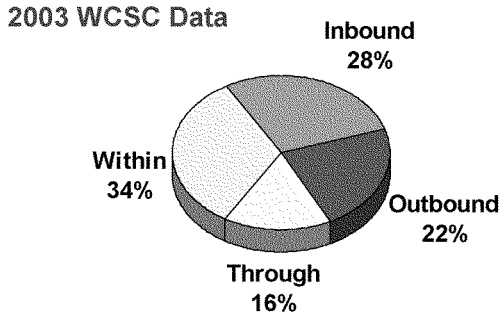
Figure 4-3
Ohio River Mainstem Plan and Profile



4.5 TONNAGE GROWTH AND COMMODITY MIX

The ORB states, parts of which are drained by the Ohio River and its tributaries, are home to over 31.5 million people. Pittsburgh, Cincinnati, Columbus, Indianapolis, Louisville, and Nashville are the region's largest cities. Waterborne commerce is made possible in the basin by a series of 56 lock and dam structures spread throughout the Ohio River and its 12 navigable tributaries (see **Figure 4-1** above). In recent years, barges on the Ohio River mainstem have carried an average of 238 million tons of bulk commodities. These commodities are the products of coal mines, petroleum refineries, stone quarries, cement plants, and farms and the raw material for construction companies, steel mills, electric utilities, paper plants, aluminum manufacturers, and chemical companies; the foundation of the region's economy. As can be seen in **Figure 4-4** below, a large percentage of this traffic (34 percent) is internal to or within the mainstem.

FIGURE 4-4
Inbound, Outbound, Through and Within
Ohio River Mainstem Traffic



Source: WCSC data.

Basin river transportation revolves around the movement of coal and other bulk commodities, traffic most efficiently carried by water. The ORS extends this efficiency deep into the interior of the North American continent. The availability of this form of transportation, along with the availability of rich deposits of coal (approximately 70 billion tons of demonstrated reserves), has made Pittsburgh, Pennsylvania and Huntington, West Virginia, the second and fourth largest coal ports, respectively, in the United States. Most of the basin's coal moves to domestic markets -- primarily to the electric utility industry. Over the last 30 years, much of the region's electricity generating capacity has moved away from small streams and large cities to the more rural areas of the Ohio River and its system of navigable rivers. Dependable supplies of cooling water and access to low-cost transportation are the primary attractions. In fact, electric utility companies account for nearly half of system traffic.

The main artery of the Ohio River System is the mainstem Ohio. Eighty-nine percent of ORS traffic moves on the Ohio River mainstem (see **Table 4-2**). Long term growth on the Ohio River has proceeded at a faster pace than the system as a whole, reflecting the early development of the mainstem as compared with some of the tributary streams like the Monongahela and Kanawha rivers. While growth in the last thirteen years on the mainstem Ohio has slowed considerably from its 1940-2004 annual growth rate of 3.4 percent, it continues to support substantial commercial traffic (see **Table 4-3**).

TABLE 4-2
Historic Ohio River System and Mainstem Ohio Traffic
(Million Tons)

Year	ORS	Ohio River	% ORS
1940	51.2	29.5	58%
1950	66.1	48.6	74%
1960	105.3	79.5	75%
1970	163.9	129.6	79%
1980	200.5	160.7	80%
1990	257.8	225.7	88%
2000	271.7	236.5	87%
2004	269.9	239.0	89%
Annual Growth:			
- 1940-04	2.7%	3.4%	
- 1990-04	0.1%	0.1%	

Source: USACE Waterborne Commerce Statistics

TABLE 4-3
Historic Ohio River Mainstem Traffic by Commodity
(Million Tons)

Year	Coal	Petrol	Aggs	Grain	Chem	Ores	Iron	Other	Total
1965	46.6	20.5	14.2	2.6	6.0	7.6	3.4	2.3	103.2
1970	59.0	25.3	17.2	3.6	10.6	3.9	4.4	5.5	129.5
1975	73.3	19.6	16.5	4.1	9.1	3.5	3.9	10.1	140.1
1980	86.1	18.3	21.2	6.7	11.5	3.2	4.1	9.6	160.7
1985	98.2	12.5	20.9	11.7	12.7	3.5	5.0	13.4	177.9
1990	135.1	14.4	30.4	13.2	9.3	5.5	6.5	11.2	225.6
1991	131.6	13.9	27.0	10.2	9.0	5.7	6.2	14.8	218.4
1992	134.7	13.3	28.1	11.3	9.6	5.5	5.8	18.1	226.4
1993	130.3	14.2	29.5	14.0	10.5	5.9	7.5	17.6	229.5
1994	134.8	14.2	32.2	12.0	10.2	6.8	9.6	17.0	236.8
1995	130.0	13.6	33.3	12.0	10.2	6.7	10.1	18.2	234.1
1996	134.8	13.2	37.3	10.7	9.4	7.5	9.7	15.1	237.7
1997	135.1	12.8	39.9	10.9	9.6	6.8	9.5	15.4	240.0
1998	132.7	20.2	42.9	13.9	9.8	5.9	10.2	6.3	241.9
1999	124.8	20.6	43.2	15.2	10.0	6.6	12.1	8.4	240.9
2000	118.9	20.2	40.9	15.6	10.2	6.9	14.3	9.5	236.5
2001	128.0	20.3	40.8	18.0	9.7	6.8	10.9	7.9	242.4
2002	131.0	19.7	39.1	16.9	9.7	6.4	12.4	7.6	242.8
2003	118.5	16.3	41.7	13.8	10.3	7.4	13.9	6.8	228.8
Avg. Ann. Growth Rate									
(1965 - 2003)	**2.5%**	**-0.6%**	**2.9%**	**4.5%**	**1.4%**	**-0.1%**	**3.8%**	**2.9%**	**2.1%**
(1993 - 2003)	**-0.9%**	**1.4%**	**3.5%**	**-0.1%**	**-0.2%**	**2.3%**	**6.4%**	**-9.1%**	**0.0%**

Source: WCSC data.
Note: Asphalt was reclassified as Petrol in 1998. Previously asphalt was grouped in Other.

SECTION 5
VESSEL FLEET AND LOCK UTILIZATION

5.1 INTRODUCTION

Tows moving on the inland waterway system are configured to operate as efficiently as possible along each waterway segment. Lock size and channel dimensions are critical in establishing the most efficient tow configuration. Currently, the Ohio River fleet consists largely of jumbo barges, 15 of these barges comprising a typical tow. This section describes the existing characteristics of barges and tows using mainstem locks and their performance in processing commercial traffic. Detailed discussions of the vessel fleet and lock utilization are presented in **Attachment 2 Capacity Analysis** of this economics appendix.

5.2 VESSEL FLEET

5.2.1 Introduction

The Ohio River vessel fleet consists of different types of barges and towboats arranged in a variety of tow sizes determined by market conditions consistent with lock sizes and channel dimensions.

5.2.2 Barge Types

When mainstem locks were modernized in the 1950s, 1960s and 1970s the "standard" barge on the Ohio River was 175' long and 26' wide. Over the years, this barge type gave way to a larger 195'–200' long and 35' wide jumbo barge. Today, super and giant sized jumbo barges measuring 245'-260' long and 35'-52' wide are becoming more prevalent on the lower Ohio River, though jumbo barges remain more numerous. **Table 5-1** describes the dimensions, loading capacity and typical commodities carried by mainstem barges. The dominant barge type is overwhelmingly the jumbo hopper. These barges typically move coal, aggregates, ores, and iron and steel scrap and carry collectively 73 percent of mainstem tonnage Jumbo hoppers comprise 72 percent of the mainstem fleet. The larger super and giant jumbo hoppers are mainly used on the lower river and reflect the shippers and markets served in that region. **Table 5-2** describes the average annual number of trips and tons by barge type used on the mainstem from 1990 to 2000. Average annual loadings from 1990 to 200 for the barge types listed in tables 5-1 and 5-2 are displayed in **Figure 5-1**. The jumbo hopper on the mainstem averages about 1,550 tons per barge. Giant jumbo hoppers, found mostly on the lower Ohio, average almost 2,900 tons per loaded barge.

TABLE 5-1
Description of Barge Types

Barge Type	Dimension	Capacity (Ktons)	Typical Commodities
Hopper			
Irregular	135'x27'	867	Aggregates
Standard	175'x26'	1,069	Coal, Aggregates
Stumbo	195'x26'	1,121	Coal
Jumbo	**195'x35'**	**1,669**	**Coal, Aggregates, Ores & Iron**
Covered Jumbo	195'x35'	1,764	Grains, Chemicals
Super Jumbo	245'x35'	2,106	Coal, Aggregates
Giant Jumbo	260'x52'	3,329	Coal, Grains, Aggregates and Coke
Tanker			
Jumbo	195'x35'	1,454	Petroleum Products & Chemicals
147'	147'x52'	1,711	Petroleum Products & Chemicals
175'	175'x54'	2,317	Petroleum Products & Chemicals
264'	264'x52'	2,820	Petroleum Products & Chemicals
290'	290'x54'	3,295	Petroleum Products & Chemicals

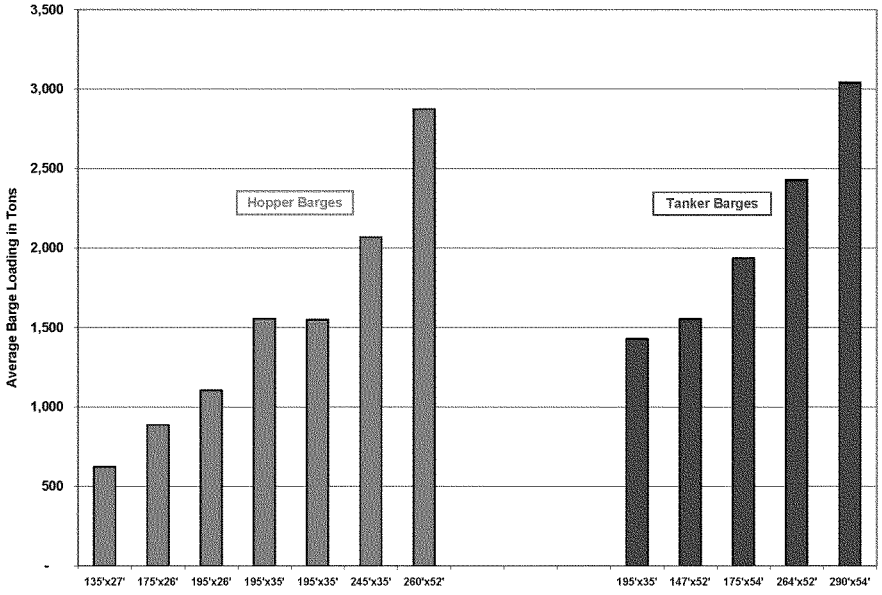
Source: COE LPMS Data.

TABLE 5-2
Annual Ohio River Trips and Tonnage by Barge Type
Averaged Over 1990 – 2000

Barge Type	Dimension	Avg. Annual		Percent of Total	
		Trips	Tons*	Trips	Tons
Hopper					
Irregular	135'x27'	3,215	2,004,284	2%	1%
Standard	175'x26'	5,571	4,943,714	4%	2%
Stumbo	195'x26'	8,535	9,428,949	6%	5%
Jumbo	**195'x35'**	**97,691**	**151,960,762**	**72%**	**73%**
Covered Jumbo	195'x35'	7,752	12,002,606	6%	6%
Super Jumbo	245'x35'	390	807,399	0%	0%
Giant Jumbo	260'x52'	869	2,497,370	1%	1%
Sub-Total		124,023	183,645,084	91%	88%
Tanker					
Jumbo	195'x35'	5,005	7,153,370	4%	3%
147'	147'x52'	1,734	2,695,467	1%	1%
175'	175'x54'	643	1,244,841	0%	1%
264'	264'x52'	1,188	2,886,932	1%	1%
290'	290'x54'	3,749	11,405,339	3%	5%
Sub-Total		12,319	25,385,949	9%	12%
Total		136,341	209,031,033	100%	100%

Source: WCSC data
* excludes intra-pool traffic

FIGURE 5-1
1990-2000 Average Barge Loadings by Barge Type

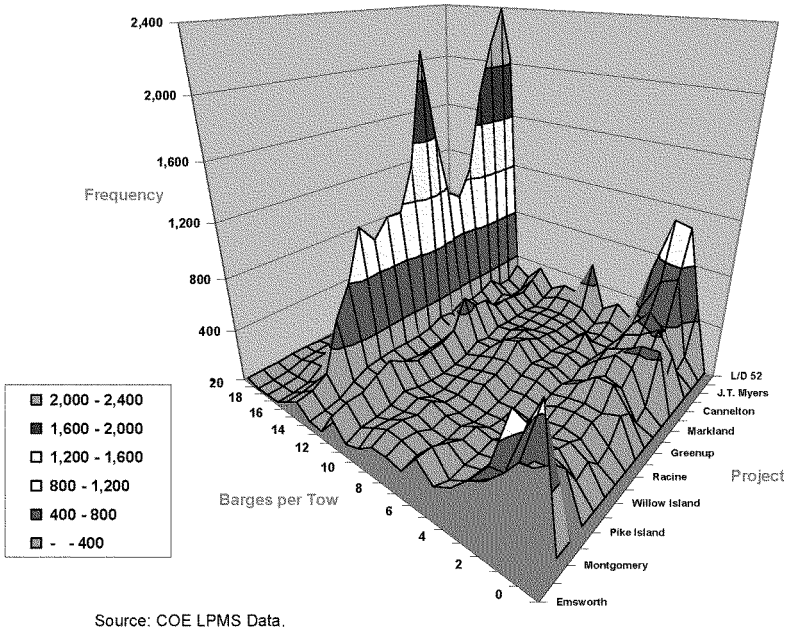


5.2.3 Tow Size Characteristics

Figure 5-2 displays tow size distributions for the mainstem projects. Tankers tend to move in 2 barge tows and they typically move petroleum products, chemicals, and asphalt on the upper and lower Ohio. Four-barge tows are normally sand-flats (irregulars). Jumbos tend to move in 12- or 15-barge tows. A fifteen-barge tow is the most common for all projects except at the upper three locks – Emsworth, Dashields and Montgomery (EDM). Ohio River tows tend to take advantage of the 1200-foot main lock chambers. These chambers can accommodate up to 17 jumbo barges, 12 super jumbo barges, or 8 giant jumbo barges in a single lockage.

Average tow sizes are shown in **Table 5-3**. The average tow size tends to increase going downstream as the percentage of 15-barge tows increases along with the use of giant jumbo hoppers and the percentage of empty barges decreases.

FIGURE 5-2
Tow Size Distributions



Source: COE LPMS Data.

TABLE 5-3
Average Tow Sizes

Project	Total Barges Per Tow	Loaded Barges Per Tow	Tons Per Tow	Tons Per Loaded Barge
Emsworth	6	4	4,845	1,352
Dashields	6	4	5,298	1,327
Montgomery	7	4	5,861	1,375
New Cumberland	9	5	7,901	1,472
Pike Island	9	6	8,667	1,482
Hannibal	11	7	11,099	1,494
Willow Island	11	8	11,527	1,502
Belleville	11	8	11,971	1,508
Racine	11	8	11,482	1,511
R.C. Byrd	11	7	11,481	1,556
Greenup	11	7	10,409	1,585
Meldahl	11	7	11,505	1,603
Markland	10	7	10,702	1,593
McAlpine	10	7	10,678	1,594
Cannelton	11	8	11,916	1,569
Newburgh	11	7	11,058	1,565
J.T. Myers	11	8	12,187	1,606
Smithland	11	7	11,250	1,613
L/D 52	10	6	9,999	1,616

Source: COE LPMS Data.

5.2.4 Traffic Statistics

Commodity traffic flow at mainstem projects is largely determined by geographic location. The commodity mix, in turn, influences barge type and tow configuration. Greenup, Meldahl, and Markland locks are characterized by predominantly downbound traffic. Most of the traffic at these facilities moves to docks on the lower Ohio River. All other mainstem projects, above and below these three locks, are characterized by mostly upbound traffic. Above Greenup is a heavy concentration of shipments from the port of Huntington which includes the Big Sandy and Kanawha rivers. Below Greenup is Cincinnati, a large consumption and destination area for barge commerce. **Table 5-4** summarizes commodity traffic by direction at the projects from 2000 to 2004. Downbound coal originating on the Big Sandy and Kanawha rivers dominates Greenup, Meldahl, and Markland traffic while that of lower river projects have more upbound coal.

TABLE 5-4
2000-2004 Average Commodity Traffic by Direction
(Ktons)

Project	Direction	Coal	Petrol	Aggs	Grains	Chem	Ores & Minerals	Iron & Steel	Other	Total
Emsworth	Up	7,463	689	1,170	31	598	557	362	283	11,153
	Down	8,519	130	622	1	179	49	360	133	9,992
Dashields	Up	7,415	818	2,075	37	666	591	391	317	12,310
	Down	8,560	161	248	1	190	64	411	126	9,760
Montgomery	Up	8,027	975	1,786	41	901	737	708	532	13,708
	Down	8,899	198	120	3	219	59	470	167	10,135
New Cumberland	Up	16,110	1,541	1,384	80	1,563	997	1,427	1,514	24,615
	Down	6,694	607	82	23	292	55	708	288	8,749
Pike Island	Up	19,910	1,774	1,432	93	1,589	1,093	3,173	1,826	30,890
	Down	7,299	718	97	28	246	64	1,264	339	10,055
Hannibal	Up	16,583	1,818	1,663	94	1,577	1,564	3,153	2,045	28,496
	Down	17,878	660	224	28	381	69	1,351	510	21,099
Willow Island	Up	16,556	1,819	1,852	103	1,437	1,600	3,147	2,421	28,935
	Down	14,890	747	177	31	391	78	1,352	544	18,209
Belleville	Up	17,059	2,334	2,624	109	2,082	1,756	3,350	2,586	31,899
	Down	15,037	607	144	28	357	93	1,358	557	18,181
Racine	Up	17,117	2,367	2,335	111	2,074	2,028	3,395	2,659	32,086
	Down	15,082	603	788	28	366	113	1,350	568	18,899
R.C. Byrd	Up	16,426	3,447	4,364	137	2,738	2,074	3,453	3,093	35,734
	Down	17,274	618	181	36	389	114	1,382	631	20,625
Greenup	Up	4,981	1,613	4,544	166	3,215	2,180	4,489	2,807	23,996
	Down	34,543	5,285	196	48	572	160	1,504	656	42,964
Meldahl	Up	2,988	1,782	4,178	170	3,287	2,308	4,635	2,310	21,658
	Down	28,405	5,191	317	57	577	186	1,445	849	37,028
Markland	Up	3,264	2,199	4,019	262	4,881	3,135	5,542	3,155	26,456
	Down	16,342	2,859	216	2,170	530	168	1,693	917	24,896
McAlpine	Up	7,847	2,365	3,296	328	5,254	3,443	6,448	3,412	32,392
	Down	10,660	2,928	427	2,870	748	179	2,097	910	20,820
Cannelton	Up	10,277	3,096	1,251	311	5,554	3,446	6,387	2,945	33,268
	Down	9,770	1,257	4,403	2,907	757	298	2,137	1,034	22,562
Newburgh	Up	17,695	3,597	1,230	585	5,957	4,563	6,579	3,396	43,601
	Down	7,921	1,236	4,063	3,663	747	359	2,179	1,182	21,351
J.T. Myers	Up	16,972	4,591	1,240	445	6,748	4,972	6,783	3,517	45,268
	Down	11,547	1,028	715	6,361	758	363	2,303	1,170	24,246
Smithland	Up	16,326	4,608	973	439	6,824	4,993	6,817	3,521	44,500
	Down	18,015	1,025	4,227	6,935	773	351	2,297	1,250	34,873
L/D 52	Up	16,941	7,104	1,950	3,270	8,413	5,855	8,173	4,430	56,135
	Down	9,347	875	12,376	8,014	1,333	383	2,758	2,141	37,227

Source: COE LPMS Data.

Table 5-5 shows the average annual growth of traffic at all mainstem projects from 1994 to 2004 and the higher level of traffic on the lower river.

TABLE 5-5
1994 - 2004 Ohio River System Traffic by Project
(Ktons)

Project	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Annual Rate 1994-2004
Emsworth	24,272	23,075	23,424	23,201	23,153	23,561	22,334	21,729	23,687	19,211	18,791	-2.5%
Dashields	25,602	24,551	24,765	24,452	24,563	24,528	23,230	22,839	24,516	20,012	19,679	-2.6%
Montgomery	27,313	25,515	27,132	26,480	26,866	26,560	25,974	25,555	26,709	21,093	20,260	-2.9%
New Cumberland	37,272	36,745	36,584	35,564	35,425	33,906	34,062	33,854	35,251	32,189	31,478	-1.7%
Pike Island	43,643	43,309	43,729	41,345	43,027	41,276	41,460	41,682	43,634	39,062	38,912	-1.1%
Hannibal	47,783	42,783	46,596	44,812	47,627	47,258	48,344	49,476	51,200	48,884	50,101	0.5%
Willow Island	45,802	44,534	43,932	42,299	44,766	44,320	45,635	46,975	48,422	46,592	48,123	0.5%
Belleville	48,641	47,122	47,869	45,511	48,688	47,983	49,201	49,243	51,118	49,482	51,380	0.5%
Racine	49,845	48,000	48,933	46,644	49,517	48,646	50,022	50,239	51,764	50,625	52,308	0.5%
R.C. Byrd	56,079	58,649	59,406	56,337	57,855	55,970	57,879	58,108	54,898	53,164	57,775	0.3%
Greenup	68,695	67,573	67,262	69,891	70,635	70,044	71,713	70,563	65,915	62,135	64,502	-0.6%
Meldahl	64,627	63,376	61,270	62,246	63,739	62,784	63,391	63,813	57,771	53,222	55,262	-1.6%
Markland	60,011	57,757	54,680	55,090	55,119	54,850	56,062	55,807	49,625	45,248	50,050	-1.8%
McAlpine	61,943	57,609	53,980	52,823	52,857	54,835	55,790	56,170	51,893	49,482	52,753	-1.6%
Cannelton	64,257	59,513	56,782	56,240	54,386	56,650	55,786	56,653	55,841	54,002	56,888	-1.2%
Newburgh	76,779	72,052	68,300	65,407	64,131	64,509	64,433	66,527	64,200	62,475	67,151	-1.3%
J.T. Myers	85,718	82,108	77,603	76,218	74,151	71,393	72,447	75,290	68,961	62,655	67,880	-2.3%
Smithland	93,337	89,145	85,077	84,931	84,606	82,115	82,610	85,915	79,040	72,305	77,020	-1.9%
L/D 52	101,267	97,467	94,052	94,770	97,695	95,125	94,687	96,715	93,382	87,420	94,954	-0.6%

Source: LPMS Data.

Average lock performance characteristics averaged for each lock from 2000 to 2004 are listed in **Table 5-6**. The number of empty barges indicates the level of backhaul opportunities. The percentage of empty barges is an important statistic when estimating lock capacity, where lock capacity is defined as an annual tonnage throughput based partially on fleet characteristics. Fifty-percent empty indicates the absence of backhaul opportunity with barges moving loaded in one direction and empty in the opposite direction. Mainstem projects range from 30 to 40 percent empty indicating some backhaul opportunity. This is largely due to the fact that mainstem projects tend to serve regions that are both production and consumption oriented, like the Gulf Coast and the Tennessee Valley, so that greater opportunities exist for loaded backhauls. Backhauling imported ore and steel products during the latter 1990s reduced the percentage of empty barges at lower Ohio projects.

5.2.5 Lock Transit Time

The time required for a tow to transit a lock has two components: processing time and delay time. Average processing and delay times from 2000 to 2004 for all the mainstem projects are provided in **Table 5-6**. Processing time is the amount of time a lock is obligated to serve a particular tow. Delay time is the time a tow must wait to be served. Under normal operation, mainstem locks experience an average 30-45 minutes of "residual" delay; delay due to a tow arrival when the lock is in use. More variability is seen in average delay time compared to average processing time. Heavier use of the auxiliary chamber during main chamber closure accounts for most increases in processing time as single-cut tows configured for the main

chamber require two cuts when using the auxiliary chamber. Higher than normal delays are generally attributable to a main chamber closure.

TABLE 5-6
2000-2004 Average Lock Performance Characteristics

Project	No. Tows	Number of Barges			Avg. Barges /Tow	Ktons	Avg. Tons /Tow	Avg. Time /Tow (min.)			Comm. Lockages	Avg Lock Cuts/Tow
		Loaded	Empty	Total				Delay	Process	Total		
Emsworth	4,433	15,524	9,419	24,942	5.6	21,145	4,770	54.7	59.9	114.6	5,301	1.2
Dashields	4,279	16,521	10,188	26,709	6.2	22,055	5,154	37.7	62.0	99.7	5,132	1.2
Montgomery	4,325	17,272	9,713	26,985	6.2	23,925	5,532	69.6	66.3	135.9	5,432	1.3
New Cumberland	4,324	22,582	15,577	38,159	8.8	33,367	7,717	28.0	58.8	86.8	4,402	1.0
Pike Island	4,852	27,520	18,266	45,786	9.4	40,950	8,440	29.3	55.0	84.3	4,954	1.0
Hannibal	4,503	33,118	15,694	48,813	10.8	49,596	11,013	21.1	53.0	74.1	4,503	1.0
Willow Island	4,098	31,384	13,594	44,978	11.0	47,147	11,505	32.6	58.4	91.1	4,154	1.0
Belleville	4,182	33,210	14,684	47,894	11.5	50,079	11,974	23.1	54.8	77.8	4,185	1.0
Racine	4,381	33,774	15,090	48,864	11.2	50,974	11,634	32.0	60.8	92.8	4,381	1.0
R.C. Byrd	4,931	36,292	16,005	52,297	10.6	56,356	11,428	36.6	58.0	94.6	4,983	1.0
Greenup	6,279	42,223	26,491	68,714	10.9	64,957	10,345	108.7	51.2	159.9	6,514	1.0
Meldahl	5,119	36,522	20,363	56,885	11.1	58,686	11,464	94.9	58.5	153.4	5,393	1.1
Markland	4,783	32,155	14,803	46,958	9.8	51,348	10,736	53.3	57.8	111.2	4,844	1.0
McAlpine	5,026	33,276	13,827	47,103	9.4	53,182	10,581	72.6	58.0	130.6	5,012	1.0
Cannelton	4,816	35,465	16,173	51,638	10.7	55,800	11,585	40.1	59.7	99.8	4,880	1.0
Newburgh	5,915	41,377	22,619	63,996	10.8	64,919	10,975	35.5	50.6	86.2	6,078	1.0
J.T. Myers	5,778	43,294	21,853	65,147	11.3	69,412	12,014	80.4	52.5	133.0	6,032	1.0
Smithland	7,147	49,249	25,513	74,763	10.5	79,350	11,103	11.9	48.0	59.8	7,276	1.0
L/D 52	9,269	57,818	31,157	88,975	9.6	93,405	10,077	118.1	22.3	140.4	9,171	1.0

Source: LPMS Data.

5.2.5.1 Processing Time

Processing time encompasses the amount of time it takes to approach, enter, chamber, and exit the chamber. At smaller chambers where multiple cuts of the tow must be performed chambering time includes all intermediate entries and exits. For example, a 15-jumbo barge tow (approximately 1140' in length) is processed in one lockage operation through a 1200' main chamber and two lockage operations to process through a smaller 600' auxiliary chamber. As a result, extra entry, exit, and chamber turnback times are experienced.

Processing times are also affected by site characteristics like hydraulic conditions, lift, number of valves, chamber size, and the location of arrival points. Tow sizes also affect processing times. Smaller tows can generally be processed faster.

Average processing time for a given lock chamber can vary from year to year depending on a number of factors. Most important are tow size, the share of the project's total tows locked through the smaller auxiliary, and the number of recreational boats relative to the number of tows. The larger the tow, the higher the average processing time since larger tows take longer to lock and in the event of a main chamber closure, would require multiple lockages to lock through the auxiliary chamber. The greater the number of recreation boats vis-à-vis tows, the shorter the average processing times because recreation vessels can lock through more quickly.

5.2.5.2 Delay Time

Delays are recorded in the Lock Performance Monitoring System (LPMS) data whenever a tow reaches a given lock's arrival point and must wait for service. Once the lock is available for service and the tow begins its approach, the period of delay ends. Delays are encountered for a variety of reasons including: weather, hydraulics, accidents, lock maintenance, and an existing queue of tows waiting to use the lock. Delays are a problem at mainstem projects when the main chamber is closed for maintenance because at current traffic levels tows arrive faster than they can be processed with the smaller auxiliary chamber.

5.3 LOCK OPERATIONS

5.3.1 Towing Operations

During normal operations, the main chamber at mainstem projects is used predominantly by large tows and the auxiliary chamber is used by single cut tows of less than 600' in length, recreational traffic, and other smaller vessels like lightboats. The maximum number of cuts allowed is a single cut through the main chamber and a double cut through the auxiliary chamber except at the upper three projects where, due to smaller size, double cut lockages are allowed at the main chamber and five-cut lockages at the auxiliary lock chamber. Furthermore, multiple cut lockages are allowed in the auxiliary chamber during periods of closure of the main chamber. **Table 5-7** shows chamber utilization by vessel type averaged from 2000 to 2002.

TABLE 5-7
Usage by Chamber, 2000-2004

	Main Chamber			Auxiliary Chamber			Both Chambers		
Project	Tows	Lt. Boats	Rec. Boats	Tows	Lt. Boats	Rec. Boats	Tows	Lt. Boats	Rec. Boats
Emsworth	3,473	122	208	961	826	2,483	4,433	947	2,691
Dashields	3,495	67	127	782	544	1,949	4,277	611	2,076
Montgomery	3,522	79	59	800	526	1,268	4,321	605	1,327
New Cumberland	3,237	52	62	1,086	211	1,898	4,323	264	1,960
Pike Island	3,802	55	56	1,049	221	1,242	4,852	276	1,298
Hannibal	4,011	39	108	491	58	1,039	4,503	97	1,146
Willow Island	3,591	32	16	506	78	1,540	4,097	110	1,556
Belleville	3,898	27	28	284	49	867	4,182	76	895
Racine	3,995	45	99	384	83	697	4,380	128	797
Byrd	4,367	59	39	564	209	763	4,931	268	801
Greenup	5,648	117	75	630	297	579	6,278	414	655
Meldahl	4,764	98	615	349	98	2,439	5,112	195	3,054
Markland	4,373	21	208	406	35	2,902	4,780	56	3,110
McAlpine*	4,947	309	564	4	1	0	4,951	309	564
Cannelton	4,484	33	192	331	53	775	4,815	86	967
Newburgh	5,357	32	140	558	251	1,095	5,915	283	1,236
Myers	5,280	33	144	497	142	1,828	5,776	175	1,971
Smithland	3,418	136	816	3,726	146	728	7,144	282	1,544
L/D 52	7,927	467	263	1,290	330	440	9,218	797	703

* McAlpine auxiliary chamber closed due to construction of new 1200' x 110' chamber
Source: COE LPMS Data.

5.3.2 Lock Operating Hours

All mainstem projects are operated year-round on a 24-hour basis except during periods when a chamber is closed due to weather or for inspection and maintenance/repair work.

5.3.3 Lockage Policy

Tows are normally locked through on a first-come/first-serve basis. Typically tows under 600' use the auxiliary chamber and tows greater than 600' use the main chamber. Nearly all of the tows at mainstem projects other than Emsworth, Dashields and Montgomery, require one-cut. EDM tows typically require two cuts. During periods when the main chamber is closed for maintenance/repair, tow haulage units are used at EDM, lock masters implement n-up/n-down lockage policies and carriers implement a self-help program. This involves using the towboats in queue to extract the first cut of a two-cut lockage from the auxiliary chamber in order to speed up the lockage process. The program is planned in cooperation with the carriers and supervised by the lockmaster. **Table 5-8** lists chamber dimensions for mainstem projects.

TABLE 5-8
Mainstem Lock Chamber Dimensions

Project	Main	Auxiliary
Emsworth	600' x 110'	360' x 56'
Dashields	600' x 110'	360' x 56'
Montgomery	600' x 110'	360' x 56'
New Cumberland	1200' x 110'	600' x 110'
Pike Island	1200' x 110'	600' x 110'
Hannibal	1200' x 110'	600' x 110'
Willow Island	1200' x 110'	600' x 110'
Belleville	1200' x 110'	600' x 110'
Racine	1200' x 110'	600' x 110'
Byrd	1200' x 110'	600' x 110'
Greenup	1200' x 110'	600' x 110'
Meldahl	1200' x 110'	600' x 110'
Markland	1200' x 110'	600' x 110'
McAlpine*	1200' x 110'	1200' x 110'
Cannelton	1200' x 110'	600' x 110'
Newburgh	1200' x 110'	600' x 110'
Myers	1200' x 110'	600' x 110'
Smithland	1200' x 110'	1200' x 110'
Olmsted*	1200' x 110'	1200' x 110'

* new 1200' x 600' chamber became operational in 2009

5.4 VESSEL FLEET, LOCK PROCESSING TIME AND CAPACITY

Chamber dimensions, vessel fleet characteristics and lock processing time are the major factors that determine a project's capacity for annual tonnage throughput. Lock capacity, in this study, is defined as the level of tonnage where the tonnage-delay curve reaches its vertical asymptote and average tow delay increases without bound. Lock capacity analysis, developed using the WAM, is more fully discussed in **Attachment 2, Capacity Analysis**. This definition of capacity is a useful descriptive measure but does not measure economic capacity. Despite sharing identical physical dimensions, Mainstem locks can be expected to have different capacities based upon significant differences in vessel fleets and processing times (see **Table 5-9**). Given this definition of capacity, differences in capacity estimates can be attributed to differences in barge loadings, tow sizes, percent empty barges (more backhaul opportunity) and lock processing times. The three upper Ohio projects have the lowest capacity owing to their smaller size. Available capacity and traffic levels tend to be higher at the downstream projects.

TABLE 5-9
Comparative Mainstem Lock Capacity

Project	Main	Auxiliary	Both
Emsworth	39.4	12.6	45.8
Dashields	46.5	12.9	51.7
Montgomery	43.9	12.9	47.6
New Cumberland	78.5	44.5	132.9
Pike Island	99.5	47.9	151.2
Hannibal	103.1	52.4	152.1
Willow Island	107.5	54.2	155.1
Belleville	114.6	56.3	167.2
Racine	110.5	54.0	151.1
Byrd	116.3	55.5	151.0
Greenup	113.3	54.3	144.2
Meldahl	116.3	55.5	151.0
Markland	119.0	57.1	160.5
McAlpine*	120.0	123.0	225.5
Cannelton	124.0	59.0	162.1
Newburgh	135.6	61.7	169.8
Myers	137.3	63.6	170.6
Smithland	143.4	132.9	264.4
Olmsted*	NA	NA	274.9

* under construction

SECTION 6
HISTORIC and PROJECTED TRAFFIC

6.1 GENERAL

This section discusses historic, existing, and projected future traffic on the ORS and the Ohio River mainstem. Historic developments that led to the growth of waterborne traffic on the ORS are also discussed. The methodology used in projecting future traffic demands is summarized along with the projection results. A more detailed discussion of the traffic forecasts used in this analysis can be found in **Attachment 4 Traffic Demand Forecasts**.

6.2 EXISTING TRAFFIC

The mainstem Ohio River handled about 229 million tons of traffic in 2003, representing about 88 percent of the traffic on the Ohio River System (ORS). The Ohio River handled all of the petroleum fuels moving on the ORS in 2003, and nearly all of the grains, chemicals, ores and minerals, and iron and steel traffic. The mainstem handled a considerably smaller share of the system's coal and coke and aggregates traffic. The commodity traffic distribution for the Ohio River and the ORS are shown in **Figure 6-1**. **Table 6-1** shows 2003 traffic by commodity group for the Ohio River and the ORS.

Figure 6-1
Commodity Traffic Distribution, 2003

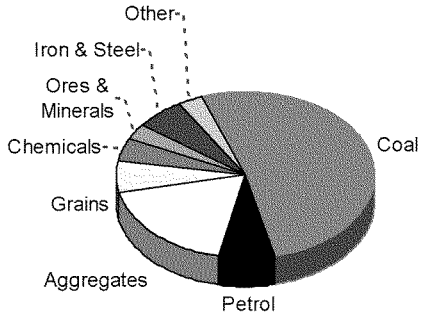


TABLE 6-1
Commodity Traffic on Ohio River Mainstem and the ORS, 2003
(Million Tons)

Commodity	ORS	Ohio River	Ohio River % of ORS
Coal & Coke	140.9	118.5	84.1%
Petroleum	16.8	16.3	97.0%
Aggregates	47.4	41.7	88.0%
Grains	14.1	13.8	97.9%
Chemicals	11.4	10.3	90.4%
Ores & Minerals	7.4	7.4	100.0%
Iron & Steel	14.3	13.9	97.2%
Other	7.4	6.8	91.9%
TOTAL	259.7	228.7	88.1%

Source: WCSC data

The leading commodity group on the Ohio River in 2003 was coal and coke, which accounted for about 52 percent of total traffic. A large majority of this traffic (over 83 percent) was utility steam coal. Other destinations were coking plants (7 percent), industrial facilities (6 percent), and the export market (1 percent). Aggregates were about 18 percent of total Ohio River traffic, followed by petroleum products (7.1 percent), iron and steel products (6.1 percent), grains (6.0 percent), and chemicals (4.5 percent). Collectively, these six commodity groups accounted for almost 94 percent of Ohio River tonnage.

6.3 HISTORIC TRAFFIC DEVELOPMENT

6.3.1 Historic Growth Factors

Since the end of the Second World War, fairly continual industrial expansion in the Ohio River Basin has produced significant increases in commodity traffic on the Ohio River. Dramatic increases occurred in the immediate post-war period as the navigation system accommodated the transportation needs of expanding basin industries, especially industries such as the primary metals industry in the Wheeling and Pittsburgh areas.

Between 1950 and 1965, traffic on the Ohio River doubled. Over the next 25 years, 1965-1990, traffic on the mainstem doubled once again. Most of this traffic growth was driven by massive investments in waterside coal-fired electric generating facilities that were expanding to accommodate the needs of an expanding economic base. Electric utilities were locating new plants along the Ohio River and expanding their existing waterside facilities to take advantage of the river as a source of water supply and for low-cost waterway transportation of coal. Since 1990, with no growth in coal traffic, the 0.6

percent annual growth in mainstem traffic has been driven by increases in aggregates, ores and minerals, and iron and steel traffic.

6.3.2 Total Traffic

Ohio River traffic for the period 1940-2004 is presented in **Table 6-2**. In 1940, mainstem traffic accounted for about 58 percent of traffic on the ORS, but throughout the 1990s and early 2000s, mainstem traffic normally accounted for 88-89 percent of total system traffic. Over the 64-year period, Ohio River traffic increased at an annual rate of about 3.4 percent, compared to a growth rate of 2.7 percent for the ORS. During the 1990s, the growth in mainstem traffic slowed substantially relative to the historic trend. Between 1990 and 2004, traffic on the Ohio River and the ORS grew at an annual rate of about 0.1 percent.

TABLE 6-2

Historic Ohio River and ORS Traffic
1940-2004
(Million Tons)

Year	ORS	Ohio River	% ORS
1940	51.2	29.5	58%
1950	66.1	48.6	74%
1960	105.3	79.5	75%
1970	163.9	129.6	79%
1980	200.5	160.7	80%
1990	257.8	225.7	88%
2000	271.7	236.5	87%
2004	269.9	239.0	89%
Annual Growth:			
- 1940-04	2.7%	3.4%	
- 1990-04	0.1%	0.1%	

Source: USACE Waterborne Commerce Statistics

6.3.3 Commodity Group Trends

6.3.3.1 General

Ohio River traffic by commodity group for selected years between 1970 and 2000 is shown in **Table 6-3**. On the mainstem, each of the major commodity groups increased in tonnage between 1970 and 2000, with the exceptions of petroleum fuels and crude petroleum. The completion of major pipeline projects into the ORB diminished the need for waterborne transport of petroleum fuels and crude petroleum. The highest annual growth rates over the 30-year period occurred for shipments in the all others category (principally cement, lime, asphalt and animal feeds); iron and steel; grains; and ores and minerals, followed by aggregates and coal and coke. Chemicals traffic was flat over the 30-year period and petroleum products and crude petroleum diminished, as previously mentioned. Between 1990 and 2000, traffic growth was dominated by iron and steel, ores and minerals, and aggregates, followed by chemicals and all others. Grains and petroleum fuels grew much more slowly over this 10-year span, while crude petroleum and coal and coke traffic diminished.

TABLE 6-
Historic Ohio River Commodity
1970 - 2000
(Million Tons)

Commodit	1970	1980	1990	1995	2000	Annual % Growth 1970-	Annual % Growth 1990-
Coal & Coke	59.0	86.1	136.7	130.3	121.8	2.4	-
Petroleum Fuels	15.5	17.7	13.4	13.4	14.1	-	0.5
Crude Petroleum	7.1	0.6	0.5	0.2	0.4	-	-
Aggregates	17.2	21.2	28.7	33.4	38.9	2.8	3.1
Grains	3.6	6.7	10.3	12.0	10.8	3.7	0.5
Chemicals	10.6	11.5	9.3	10.7	10.8	0.0	1.5
Ores & Minerals	3.9	3.2	5.5	6.7	9.1	2.9	5.2
Iron & Steel	4.4	4.1	6.5	10.1	14.3	4.0	8.2
All Others	5.5	9.6	17.0	19.0	18.9	4.2	1.0
TOTAL	126.8	160.7	225.7	235.8	236.5	2.1	0.6

SOURCE: USACE Waterborne Commerce Statistics

6.3.3.2 Coal and Coke

Over the 30-year span between 1970 to 2000, coal and coke typically accounted for around one-half of Ohio River commodity traffic. The traditional dominance of coal and coke on the Ohio River is explained, in large part, by the resource base. The eight ORB states have demonstrated reserves totaling about 237 billion tons, or about 47 percent of the nation's total. Coal production in the ORB states totaled about 488 million tons in 2001, or 43 percent of the nation's total.

Table 6-3 shows mainstem traffic in coal and coke increasing at an annual rate of 2.4 percent between 1970 and 2000 to 121.8 million tons. Over this 30-year time span, coal and coke traffic was influenced by a number of factors. During the 1970s and 1980s, utilities were expanding their coal-fired electric generating capacity along the Ohio River. The oil embargo of the mid-1970s and efforts at oil conservation increased interest in coal as an energy source. In the early 1980s, changes in the steel industry brought about greatly reduced requirements for coke (and therefore coking coal) in steel making processes. Passage of the Clean Air Act amendments (particularly the 1990 amendments) and subsequent regulations increased interest in low-sulfur coal from mines in the western U.S. and Central Appalachia, resulting in higher levels of waterborne coal traffic. Coal exports, as well, increased rapidly from the mid-1980s to the mid-1990s, at which time an economic downturn in Asia and intense competition from foreign producers caused ORS exports to diminish.

Between 1990 and 2000, **Table 6-3** shows coal and coke traffic diminishing at a rate of 1.1 percent per annum. This reflected the near disappearance of the export market for ORS coal, as well as the loss of domestic utility steam coal markets outside of the ORS, and reduced movement of Illinois Basin and Northern Appalachian coal on the system.

6.3.3.3 Petroleum Fuels

Petroleum fuels traffic on the Ohio River has diminished as a share of total traffic from about 12 percent in 1970 to 6 percent in 2000. Currently, only three refineries have direct access to the Ohio River, while two other refineries have pipeline connections to the river. The Ohio River competes with pipeline for distribution of petroleum fuels into the Ohio River Basin.

Between 1970 and 2000, petroleum fuels traffic diminished at an annual rate of 0.3 percent to 14.1 million tons. The reduction in petroleum fuels traffic on the Ohio River began in the early 1970s, when several petroleum products pipelines opened for delivery of products in the ORB states. A further decline in petroleum fuels traffic in the 1980s came about as a result of large-scale conservation measures; a recession in the early 1980s; a concentration of refinery capacity in the Gulf Coast; and the closure of some water-oriented ORB refineries. In the decade between 1990 and 2000, Ohio River petroleum fuels traffic increased at an annual rate of 0.5 percent.

6.3.3.4 Crude Petroleum

In the early 1970s, crude petroleum traffic on the Ohio River was about 6 percent of total traffic, but by 2000 had diminished to less than 1 percent. There was both a relative and absolute reduction in traffic that came about as a result of the completion of some important crude petroleum pipelines from the Gulf Coast into the ORB states to serve basin refineries. Between 1970 and 2000, crude petroleum traffic diminished at an annual rate of 9.4 percent to about 400,000 tons. Most of this traffic is internal to the ORS.

6.3.3.5 Aggregates

Aggregates traffic on the Ohio River, made up primarily of crushed limestone and sand and gravel, increased as a share of total traffic from 14 percent in 1970 to about 16 percent in 2000, making it the second largest commodity group on the Ohio River. Limestone and sand and gravel are fairly widespread throughout the Ohio River Basin, although materials suitable for specialty uses, such as coal desulfurization or cement manufacture, are more limited in availability. The primary usage of these materials is as construction aggregate, and consequently, they typically move relatively short distances from quarries or dredge sites to construction activities.

Table 6-3 shows aggregates traffic growing at a rate of about 2.8 percent per year between 1970 and 2000 to 38.9 million tons. Most of this growth was driven by the requirements for construction materials in the ORB, particularly for such activities as highway construction. Between 1990 and 2000, annual growth in aggregates accelerated to around 3.1 percent. In addition to expansions in construction activities, this reflects, in part, the reduction in ORS coal traffic, since hauling aggregate materials is an alternative usage of coal barges. It also reflects increased movement of limestone for coal desulfurization.

6.3.3.6 Grains

Grains traffic on the Ohio River increased from 3 to 5 percent of total traffic between 1970 and 2000. Within the ORB, the states of Illinois, Indiana, and Ohio are characterized as being part of the nation's Corn Belt, and all three states are important producers of corn and soybeans. Wheat is much less prominent. Grain traffic on the Ohio River is inbound or through traffic destined for Ohio or Tennessee River processors, or outbound traffic destined for the export market. Very little traffic is internal to the system.

Between 1970 and 2000, **Table 6-3** shows that grains traffic on the Ohio River increased at a rate of about 3.7 percent per year, to about 10.8 million tons. Much of this growth is associated with the expansion of grain processors on the ORS. **Table 6-3** also shows grains traffic growing much more slowly during the 1990s than during the overall 30-year period. This is explained, in large part, by a drop in export grains traffic.

6.3.3.7 Chemicals

Chemicals traffic, made up of chemical fertilizers and industrial chemicals, dropped as a share of total Ohio River traffic from 8 percent to 5 percent between 1970 and 2000, although the volume of traffic was essentially unchanged. The chemical fertilizers traffic is made up of the chemical inputs used to formulate fertilizers. This traffic originates in the Gulf Coast and moves to Ohio River fertilizer terminals. The industrial chemicals traffic is basic chemicals or intermediate chemicals used in other manufacturing activities. This traffic originates on the Gulf Coast or at chemical plants along the ORS.

The data in **Table 6-3** show that chemicals traffic grew only slightly between 1970 and 2000, reaching a level of 10.8 million tons. This is partially explained by the reclassification of alumina from the chemicals group to the ores and minerals group in 1990. Another partial explanation is the lack of growth in the movement of chemical fertilizers. The volume of chemical fertilizers consumed is related to the number of acres under cultivation, which in the ORB states has been diminishing.

6.3.3.8 Ores and Minerals

Ores and minerals traffic, which is made up primarily of salt, bauxite, and gypsum increased only slightly as a share of Ohio River traffic between 1970 and 2000, from 3 to 4 percent. Salt traffic originates on the Gulf Coast and moves to urban centers on the ORS for use as road salt or to chlor-alkali plants for the manufacture of chlorine and sodium hydroxide. Bauxite is entirely imported at this point and moves from the Gulf Coast to ORS aluminum plants. Gypsum sources are more widespread, but growth in this commodity group is resulting from coal desulfurization activities at ORS utility plants, where synthetic gypsum is produced as a by product.

Between 1970 and 2000, ores and minerals traffic increased at an annual rate of 2.9 percent to 9.1 million tons. This high growth rate is explained in part by the re-classification of alumina from the chemicals to the ores and minerals group in 1990 and by the introduction of synthetic gypsum traffic, which is a by-product of coal desulfurization at electric utilities. Synthetic gypsum is used in the manufacture of gypsum wallboard. Between 1990 and 2000, the growth rate for this commodity group increased to 5.2 percent, further underscoring the growth of synthetic gypsum traffic.

6.3.3.9 Iron and Steel

Iron and steel traffic, which includes iron ore, increased from 3.0 percent of total traffic in 1970 to about 6.0 percent in 2000. Iron and steel traffic on the Ohio River consists of imported and domestically-produced iron ore; the intermediate outputs of integrated steel mills and steel mini-mills, as well as imported products; and the iron and steel feed-stocks of steel mini-mills.

In the 30 years between 1970 and 2000, iron and steel traffic increased at an annual rate of 4 percent, reaching a level of 14.3 million tons. Over this 30-year span, iron and steel grew faster than any other group on the system. Traffic in iron and steel on the Ohio reflects the changes that have taken place in the steel industry over the last three decades.

Iron ore traffic diminished during the 1980s because a number of integrated steel mills closed, but subsequently rebounded as remaining producers turned to imported iron ore. Traffic in iron and steel scrap increased as steel mini-mills opened for operation. More intermediate steel products are moving on the system as imports have grown and steel processors have taken over some of the functions formerly carried out by integrated producers. Iron and steel traffic on the Ohio grew at an annual rate of 8.2 percent between 1990 and 2000, again fueled by growth in imported iron ore and intermediate products, as well as growth in scrap movements to mini-mills.

6.3.3.10 All Others

Traffic in the all others category, made up in large part of cement, lime, asphalt, and processed animal feed increased from 4 percent to 8 percent of Ohio River traffic between 1970 and 2000.

The data in **Table 6-3** show that traffic in the all others category grew at a faster rate (4.2 percent per annum) than any other commodity group in the 1970-2000 period. Much of the growth is associated with the opening of grain processors on the ORS that supply by-product animal feed to the export market and with the installation and operation of lime-based coal desulfurization units by the electric utilities. During the 1990-2000 period, the growth of traffic in the all others category slowed to about 1 percent per annum. The reduction in growth is attributable to a fall-off in the export market for ORS animal feed.

6.4 LOCK-LEVEL TRAFFIC

Table 6-4 shows total commodity traffic at Ohio River mainstem projects for the period 1970-2000. The highest growth rates for the 30-year period occurred at projects in the middle Ohio Valley, while the uppermost Ohio River projects had the lowest. The highest growth rates were experienced at the Greenup and Meldahl facilities. These were followed by Hannibal and Pike Island on the upper river, and Myers and Smithland on the lower river. Lock-level commodity traffic growth has been hampered in the 1990s by a substantial drop-off in export coal and grain traffic, the loss of some domestic utility steam coal markets outside of the ORS, and a reduction in the usage and waterborne movement of Illinois Basin and Northern Appalachian coals by electric utilities. The projects most severely affected during the 1990s were the lower river projects. Traffic at the uppermost Ohio River projects remained very nearly flat over the 10-year period.

6.5 PROJECTED TRAFFIC DEMANDS

6.5.1 Introduction

This section presents the current traffic demand forecasts for the Ohio River. In total, five alternative traffic demand forecasts for utility steam coal and flue gas desulfurization (FGD) sorbent materials were developed. These forecasts were combined with a single forecast for all other commodity traffic. The alternative utility-related traffic

demand forecasts reflect two distinct approaches to the forecasting problem. One is founded on extensive survey input from the utilities themselves and the other is based on a highly-detailed linear programming approach.

6.5.2 Forecasting Methodology

The ORS traffic demand forecasts presented here represent a comprehensive update of previous forecasts completed in the spring of 1999. New forecasts were prepared for all commodity groups, but because of the dominance of utility steam coal on the system and the uncertainties surrounding the regulatory future, alternative scenarios were developed only for utility coal and sorbent materials (lime and limestone) used for coal

TABLE 6-4
Historic Traffic at Ohio River Projects, 1970-2000
(Million Tons)

Project	1970	1980	1990	1995	2000	Annual % Growth 1970-	Annual % Growth 1990-
Emsworth	19.6	20.0	21.8	21.6	21.9	0.4	0.1
Dashield	20.2	21.0	23.2	22.8	22.4	0.3	-
Montgomery	17.4	20.4	25.0	25.2	25.2	1.2	0.1
New	19.2	23.2	30.4	36.5	34.2	1.9	1.2
Pike	19.8	26.4	36.0	43.9	42.3	2.6	1.6
Hanniba	22.4	30.4	36.3	47.9	49.8	2.7	3.2
Willow	25.6	31.6	34.5	45.6	47.0	2.0	3.1
Bellevill	26.1	32.6	37.0	48.4	50.9	2.3	3.2
Racin	27.0	34.0	38.2	49.0	51.5	2.2	3.0
Byrd	28.9	37.4	42.3	60.3	59.1	2.4	3.4
Greenu	28.7	34.8	56.2	71.0	74.0	3.2	2.8
Meldah	28.5	34.6	55.2	65.0	64.6	2.8	1.6
Marklan	29.4	37.8	53.6	58.8	56.0	2.2	0.4
McAlpin	33.0	41.5	58.4	60.0	55.2	1.7	-
Cannelto	38.1	43.2	62.4	60.5	54.1	1.2	-
Newburg	32.8	43.9	74.3	73.5	63.0	2.2	-
Myers	34.8	50.3	83.6	85.0	72.0	2.5	-
Smithland	39.1	58.5	91.2	89.9	81.4	2.5	-
L/D	45.9	63.0	101.4	98.2	91.8	2.3	-
L/D	43.3	53.6	87.8	87.9	85.3	2.3	-
Ohio	126.8	160.7	225.7	235.8	236.5	2.1	0.6
Ohio River	163.1	200.5	260.3	263.5	271.8	1.7	0.5

SOURCE: USACE Waterborne Commerce Statistics

desulfurization. The current round of adjustments to the utility coal forecasts was necessitated by existing and likely future regulatory changes affecting the electric utility

industry. Environmental issues are acknowledged by industry experts to be the dominant issues expected to affect future coal utilization and sourcing on the part of the electric utilities. In light of this, five alternative forecast scenarios were developed, three of which directly reflect alternative legislative approaches to emissions reductions.

The basic forecasting framework for developing waterway traffic demand forecasts is similar in most instances, the major exceptions being three of the alternative utility coal forecasts, which are based on a linear programming approach. The procedure starts with a set of base-year waterway traffic commodity flows and information about the economic prospects of the industries and individual companies consuming these waterborne commodities. The first steps in projecting waterway traffic demands are to identify the industry and market that each dock serves and to adjust commodity flows to these docks to represent base-level expectations for each facility. Adjustments are based on examination of historical flows and the results of extensive shipper surveys. Industry and market prospects are analyzed by examination of relevant industry and economic/demographic forecasts and the company-specific information obtained by means of shipper surveys. Finally, future traffic demands are generated based both on the information obtained in the shipper surveys and the application of appropriate forecast growth.

Since utility coal dominates the traffic picture on the ORS, the most detailed analyses were conducted for the utility-related commodities, i.e., utility coal and lime and limestone used in coal desulfurization. Two distinct approaches were taken to forecasting ORS utility coal traffic. One approach involved surveying the utilities themselves, soliciting information from them regarding their future coal sourcing plans in light of the environmental regulations, and using this information in the ORS utility coal model to generate future coal burn, sources and flows. The second approach involved using the output of Hill and Associates' linear programming techniques, based on the use of their National Power Model and other related models. The linear programming approach determines a least cost combination of inputs in a market context, including coal by type and source, to meet electricity demands through time.

These two basic approaches were used to generate the five alternative forecasts of ORS utility coal traffic demands. The first two of these, dubbed the Utility-Based and Utility-Based High scenarios, makes use of utility survey information and the ORS utility coal model to generate a forecast that reflects the utilities' view of the environmental regulatory future. The Utility-Based High scenario assumes high economic growth. The Hill scenarios reflect the impact of three alternative futures on ORS coal flows. The first of these is a continued application of existing law, which in this case is the National Ambient Air Quality Standards. This scenario is referred to as the NAAQS scenario. The second Hill scenario reflects implementation of the administration's multi-emissions proposal, the Clear Skies Initiative, as an amendment to the Clean Air Act. This proposal, referred to as the Clear Skies scenario could be expected to have a fairly profound impact on the use of coal by electric utilities, largely because of the proposal's implied mercury emissions restrictions. The final Hill scenario would be implementation of the Clear Skies initiative without the severe mercury restrictions that are included under Clear Skies. This scenario is referred to as the No Mercury Limitations Scenario. Additional details on the development of alternative traffic forecast scenarios are provided in **Attachment 4 Traffic Demand Forecasts**.

One additional step in the forecasting methodology involved the identification of potential induced traffic for the Upper Ohio River segment. The Emsworth, Dashields and Montgomery projects on the Upper Ohio are the only mainstem projects without 1200'x110' lock chambers. Consequently, these projects form substantial constraints to system traffic because of delays and downtime resulting from more lockage cycles at the projects. In light of this, efforts were made to identify and forecast potential traffic that could be induced to use the waterway by improvements at these projects. A separate shipper survey was conducted to identify potential induced commodity movements. As a result of the survey and subsequent screening of potential movements, almost 1 million tons of traffic were identified that would make use of an improved upper Ohio segment. Additional details on this survey and the traffic identified are provided in **Attachment 4 Traffic Demand Forecasts**.

6.5.3 Forecast Results

6.5.3.1 ORS Traffic Demands

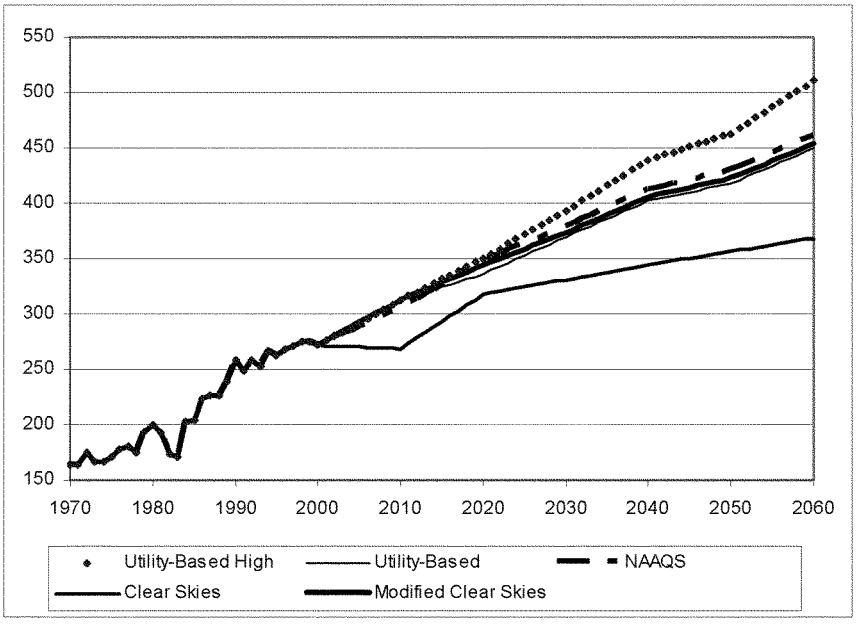
Projected traffic demands for the ORS under each of the five alternative forecast scenarios for the period 2000-2060 are displayed in **Table 6-5**. It should be noted that these forecasts do not include the induced traffic identified as a result of the survey effort described previously. **Figure 6-2** shows historical and projected ORS traffic under each of the alternative scenarios. Over the longer term, the high and low alternatives that emerge

TABLE 6-5
Actual and Projected ORS Traffic Demand, 1970-2060
(Million Tons)

	Actual								Annual % Growth	
									Actual	Projected
Scenario	1970	2000	2010	2020	2030	2040	2050	2060	1970-2000	2000-60
Utility-Based High	163.9	271.8	312.5	350.4	393.1	439.3	463.1	511.0	1.70	1.06
Utility-Based	163.9	271.8	312.5	336.4	369.8	402.2	418.0	449.9	1.70	0.84
NAAQS	163.9	271.8	305.7	348.5	379.3	412.4	429.9	461.5	1.70	0.89
Clear Skies	163.9	271.8	268.7	318.0	331.2	344.5	356.5	368.7	1.70	0.51
Modified Clear Skies	163.9	271.8	313.1	344.4	373.5	406.1	423.0	454.0	1.70	0.86

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

FIGURE 6-2
ORS Traffic Demand Forecasts



are the Utility-Based High scenario and the Clear Skies scenario. The first of these forecasts reflects the outlook of the major utility users of the ORS along with the application of the ORS utility coal model in a high economic growth framework. The second reflects implementation of the administration's Clear Skies Initiative with its expected negative impact on coal usage. In year 2020, the forecasts range between 318 million tons under the Clear Skies scenario to 350.4 million tons under the Utility-Based High scenario. By year 2060, the range is between 368.7 and 511.0 million tons for these same scenarios. Annual growth for the 2000-2060 period ranges from 0.51 percent to 1.06 percent. This is compared to annual growth over the 1970-2000 period of 1.7 percent per year.

6.5.3.2 Ohio River Traffic Demands

Table 6-6 shows total projected traffic demands for the mainstem Ohio River. Traffic demands for the mainstem show similar patterns to those for the ORS. Ohio River mainstem traffic annually accounts for about 87 percent of total system traffic throughout the forecast period. In 2020, traffic demands range between 273.6 million tons under the Clear Skies scenario to 306.1 million tons under the Utility-Based High scenario. In

TABLE 6-6
Actual and Projected Ohio River Mainstem Traffic Demand, 1970-2060
(Millions of Tons)

	Actual								Annual % Growth	
									Actual	Projected
Scenario	1970	2000	2010	2020	2030	2040	2050	2060	1970-2000	2000-60
Utility-Based High	129.6	239.0	273.3	306.1	342.2	380.0	403.4	443.2	2.06	1.03
Utility-Based	129.6	239.0	273.3	294.9	323.2	350.8	368.0	394.7	2.06	0.84
NAAQS	129.6	239.0	267.0	302.6	327.8	355.6	373.1	399.8	2.06	0.86
Clear Skies	129.6	239.0	235.1	273.6	286.1	298.9	310.6	322.3	2.06	0.50
Modified Clear Skies	129.6	239.0	271.3	297.4	320.5	347.5	364.6	390.5	2.06	0.82

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

2060, the range is between 322.3 and 443.2 million tons. Annual growth between 2000 and 2060 under Clear Skies is 0.5 percent and under the Utility-Based High scenario 1.03 percent. Over the 1970-2000 period, growth rates for traffic on the Ohio River mainstem were substantially higher than for the ORS overall (2.1 versus 1.7 percent per annum). For the forecast period, growth rates for the ORS are slightly higher under all scenarios, indicating that traffic demand growth rates for tributary streams, especially the Tennessee River, are higher than the mainstem.

6.5.3.3 Ohio River Traffic Demands by Commodity Group

Table 6-7 shows Ohio River mainstem traffic demands by commodity group. All of the commodity group forecasts are identical across the alternative forecasts except for coal and coke, aggregates and all other. Variation in the aggregates and all others forecasts occurs because the sorbent materials used in coal desulfurization are linked to the utility steam coal forecasts and these commodities, limestone and lime, fall into the aggregates and into the all others commodity groups.

The projected growth in coal and coke traffic ranges from 1.18 percent per year under the Utility-Based High scenario to 0.07 percent under the Clear Skies scenario. The growth rates for aggregates show similar patterns to the coal, 0.93 percent under the High Growth Scenario and 0.88 under Clear Skies. The growth rates are more similar to one another because aggregates traffic is dominated by construction aggregates. Growth rates for the all others group are nearly identical, ranging between 0.71 percent per annum under the NAAQS scenario and 0.71 percent under the Utility-Based and Utility-Based High scenarios. Commodity traffic in the all others category is heavily dominated by commodities other than lime used for coal desulfurization and it is assumed that any new scrubbers will be limestone and not lime-based. With respect to the other commodity

TABLE 6-

Ohio River Mainstem Traffic Demand by Commodity
2000 - 2060
(Million Tons)

Commodit	Actua 2000	Projected 2010	2020	2030	2040	2050	2060	Annual Chang 2000-
Utility-Based High:								
Coal &	121.8	137.2	153.9	177.6	203.7	217.2	246.5	1.18
Petroleum	14.1	14.7	15.4	16.2	17.0	17.7	18.5	0.45
Crude	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.27
Aggregates	38.9	49.2	57.2	61.4	63.8	65.8	67.7	0.93
Grain	10.8	12.4	14.2	16.5	19.3	20.4	21.8	1.18
Chemicals	10.8	11.9	12.5	13.4	14.8	16.3	17.9	0.86
Ores & Minerals	9.1	10.5	11.4	12.5	14.0	15.6	17.3	1.08
Iron & Steel	14.3	16.6	18.4	20.0	21.4	22.9	24.5	0.90
All	18.9	20.5	22.7	24.3	25.7	27.1	28.5	0.69
TOTAL	239.0	273.3	306.1	342.2	380.0	403.4	443.2	1.03
Utility-Based:								
Coal &	121.8	137.2	143.0	158.9	174.8	182.2	198.5	0.82
Petroleum	14.1	14.7	15.4	16.2	17.0	17.7	18.5	0.45
Crude	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.27
Aggregates	38.9	49.2	56.9	61.1	63.4	65.4	67.3	0.92
Grain	10.8	12.4	14.2	16.5	19.3	20.4	21.8	1.18
Chemicals	10.8	11.9	12.5	13.4	14.8	16.3	17.9	0.86
Ores & Minerals	9.1	10.5	11.4	12.5	14.0	15.6	17.3	1.08
Iron & Steel	14.3	16.6	18.4	20.0	21.4	22.9	24.5	0.90
All	18.9	20.5	22.6	24.3	25.7	27.1	28.5	0.69
TOTAL	239.0	273.3	294.9	323.2	350.8	368.0	394.7	0.84
NAAQS:								
Coal &	121.8	131.1	151.0	163.8	180.1	187.4	203.9	0.86
Petroleum	14.1	14.7	15.4	16.2	17.0	17.7	18.5	0.45
Crude	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.27
Aggregates	38.9	48.7	56.4	60.4	62.6	64.9	66.6	0.90
Grain	10.8	12.4	14.2	16.5	19.3	20.4	21.8	1.18
Chemicals	10.8	11.9	12.5	13.4	14.8	16.3	17.9	0.86
Ores & Minerals	9.1	10.5	11.4	12.5	14.0	15.6	17.3	1.08
Iron & Steel	14.3	16.6	18.4	20.0	21.4	22.9	24.5	0.90
All	18.9	20.8	22.9	24.5	26.0	27.4	28.8	0.71
TOTAL	239.0	267.0	302.6	327.8	355.6	373.1	399.8	0.86

TABLE 6-7

Ohio River Mainstem Traffic Demand by Commodity
2000 - 2060
(Million Tons)

Commodit	Actua 2000	Projecte 2010	2020	2030	2040	2050	2060	Annual Chang 2000-
Clear								
Coal &	121.8	99.6	122.5	122.7	124.1	125.6	127.3	0.07
Petroleum	14.1	14.7	15.4	16.2	17.0	17.7	18.5	0.45
Crude	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.27
Aggregates	38.9	48.6	56.0	60.0	62.0	64.4	65.9	0.88
Grain	10.8	12.4	14.2	16.5	19.3	20.4	21.8	1.18
Chemicals	10.8	11.9	12.5	13.4	14.8	16.3	17.9	0.86
Ores & Minerals	9.1	10.5	11.4	12.5	14.0	15.6	17.3	1.08
Iron & Steel	14.3	16.6	18.4	20.0	21.4	22.9	24.5	0.90
All	18.9	20.5	22.8	24.4	25.9	27.2	28.7	0.70
TOTAL	239.0	235.1	273.6	286.1	298.9	310.6	322.3	0.50
Modified Clear								
Coal &	121.8	135.3	145.8	156.6	172.2	179.1	194.9	0.79
Petroleum	14.1	14.7	15.4	16.2	17.0	17.7	18.5	0.45
Crude	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.27
Aggregates	38.9	48.7	56.4	60.4	62.5	64.9	66.4	0.90
Grain	10.8	12.4	14.2	16.5	19.3	20.4	21.8	1.18
Chemicals	10.8	11.9	12.5	13.4	14.8	16.3	17.9	0.86
Ores & Minerals	9.1	10.5	11.4	12.5	14.0	15.6	17.3	1.08
Iron & Steel	14.3	16.6	18.4	20.0	21.4	22.9	24.5	0.90
All	18.9	20.8	22.8	24.5	25.9	27.3	28.7	0.70
TOTAL	239.0	271.3	297.4	320.5	347.5	364.6	390.5	0.82

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

groups, the highest annual growth is forecast for grains (1.18 percent), followed by ores and minerals (1.08 percent), iron and steel (0.9 percent), chemicals (0.86 percent), petroleum fuels (0.45 percent), and crude petroleum (0.27 percent).

6.5.3.4 Lock-Level Traffic Demands

Traffic demand forecasts for the Ohio mainstem locks are displayed in **Table 6-8**. All of the forecast scenarios reflect the effects of coal switching by ORS-dependent utilities

TABLE 6-8

Projected Lock Traffic Demand
(Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Emsworth:								
Utility-Based High	21.9	24.6	25.7	27.8	29.7	30.8	33.3	0.70
Utility-Based	21.9	24.6	24.8	26.1	27.5	28.3	29.8	0.51
NAAQS	21.9	22.1	30.1	32.2	34.3	36.0	38.2	0.93
Clear Skies	21.9	19.2	24.8	24.9	25.2	25.6	26.0	0.28
Modified Clear Skies	21.9	23.9	26.9	28.6	30.4	31.9	33.8	0.72
Dashields:								
Utility-Based High	22.4	25.0	26.2	28.3	30.2	31.3	33.9	0.69
Utility-Based	22.4	25.0	25.3	26.6	28.0	28.8	30.3	0.51
NAAQS	22.4	22.5	30.6	32.7	34.8	36.5	38.8	0.92
Clear Skies	22.4	19.7	25.3	25.4	25.8	26.2	26.6	0.29
Modified Clear Skies	22.4	24.4	27.4	29.1	30.9	32.4	34.4	0.72
Montgomery:								
Utility-Based High	25.2	27.3	28.5	30.8	32.9	34.1	36.9	0.63
Utility-Based	25.2	27.3	27.6	29.1	30.6	31.6	33.3	0.46
NAAQS	25.2	26.0	34.7	37.0	39.4	41.3	43.9	0.93
Clear Skies	25.2	22.2	28.3	28.5	29.1	29.6	30.2	0.30
Modified Clear Skies	25.2	27.8	31.7	33.8	35.9	37.6	39.9	0.77
New Cumberland:								
Utility-Based High	34.2	35.8	37.0	40.1	43.0	44.5	48.5	0.58
Utility-Based	34.2	35.8	35.7	37.7	39.8	41.0	43.7	0.41
NAAQS	34.2	35.9	47.2	50.4	53.5	55.8	59.3	0.92
Clear Skies	34.2	23.5	38.2	38.6	39.3	40.1	40.9	0.30
Modified Clear Skies	34.2	42.5	43.8	46.6	49.4	51.6	54.7	0.79
Pike Island:								
Utility-Based High	42.3	46.7	48.8	53.0	56.5	58.9	64.0	0.69
Utility-Based	42.3	46.7	47.3	50.1	52.8	54.8	58.3	0.54
NAAQS	42.3	47.7	58.9	63.0	66.8	69.9	74.2	0.94
Clear Skies	42.3	35.4	51.0	51.8	53.1	54.3	55.7	0.46
Modified Clear Skies	42.3	54.3	55.8	59.5	63.0	65.9	69.9	0.84
Hannibal:								
Utility-Based High	49.8	63.0	64.8	71.4	77.1	82.1	90.7	1.00
Utility-Based	49.8	63.0	62.2	66.6	71.0	74.7	79.9	0.79
NAAQS	49.8	66.8	72.6	78.3	83.8	88.8	95.0	1.08
Clear Skies	49.8	52.0	60.6	61.6	62.9	64.3	65.8	0.47
Modified Clear Skies	49.8	70.3	75.0	80.9	86.5	91.7	98.0	1.14
Willow Island:								
Utility-Based High	47.0	59.1	61.4	67.5	72.8	77.4	85.1	0.99
Utility-Based	47.0	59.1	59.0	63.1	67.2	70.6	75.5	0.79
NAAQS	47.0	63.5	69.3	74.6	79.9	84.6	90.5	1.10
Clear Skies	47.0	48.7	57.4	58.3	59.7	61.2	62.7	0.48
Modified Clear Skies	47.0	67.0	71.7	77.2	82.7	87.5	93.6	1.15

TABLE 6-8 (cont)

Projected Lock Traffic Demand
(Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Belleville:								
Utility-Based High	50.9	63.3	65.7	72.0	77.5	82.3	90.1	0.96
Utility-Based	50.9	63.3	63.4	67.6	71.9	75.5	80.6	0.77
NAAQS	50.9	67.7	73.7	79.1	84.6	89.5	95.6	1.05
Clear Skies	50.9	52.9	61.7	62.9	64.4	66.0	67.8	0.48
Modified Clear Skies	50.9	71.2	76.1	81.7	87.3	92.4	98.6	1.11
Racine:								
Utility-Based High	51.5	63.9	66.3	72.6	78.1	82.9	90.8	0.95
Utility-Based	51.5	63.9	64.0	68.2	72.5	76.1	81.3	0.76
NAAQS	51.5	68.3	74.3	79.8	85.2	90.1	96.3	1.05
Clear Skies	51.5	53.5	62.3	63.5	65.1	66.7	68.4	0.48
Modified Clear Skies	51.5	71.8	76.7	82.4	88.0	93.0	99.3	1.10
Byrd:								
Utility-Based High	59.1	70.7	76.4	83.7	91.1	97.7	107.0	1.00
Utility-Based	59.1	70.7	73.4	78.6	84.1	88.6	94.7	0.79
NAAQS	59.1	56.9	63.2	67.3	71.9	76.0	80.8	0.52
Clear Skies	59.1	52.7	56.4	57.9	59.9	61.8	63.9	0.13
Modified Clear Skies	59.1	56.4	65.7	70.1	74.8	79.1	84.1	0.59
Greenup:								
Utility-Based High	74.0	83.9	92.9	103.0	114.2	124.2	137.0	1.03
Utility-Based	74.0	83.9	89.0	96.7	104.6	111.3	119.9	0.81
NAAQS	74.0	64.0	71.0	76.4	82.2	87.6	93.6	0.39
Clear Skies	74.0	58.5	64.6	67.4	70.6	73.6	76.9	0.06
Modified Clear Skies	74.0	63.8	72.4	78.0	83.8	89.3	95.4	0.43
Meldahl:								
Utility-Based High	64.6	72.1	77.7	85.6	94.7	102.5	112.5	0.93
Utility-Based	64.6	72.1	75.0	81.3	87.7	93.1	99.9	0.73
NAAQS	64.6	55.6	61.8	66.4	71.1	75.8	80.9	0.37
Clear Skies	64.6	50.2	54.9	57.5	60.4	63.3	66.4	0.05
Modified Clear Skies	64.6	55.4	62.6	67.3	72.0	76.7	81.9	0.40
Markland:								
Utility-Based High	56.0	65.6	68.9	75.4	82.9	88.0	95.9	0.90
Utility-Based	56.0	65.6	67.3	72.8	78.5	82.8	88.4	0.76
NAAQS	56.0	56.9	69.7	75.3	80.9	86.0	91.7	0.82
Clear Skies	56.0	51.7	63.6	66.8	70.2	73.5	76.9	0.53
Modified Clear Skies	56.0	56.2	66.8	72.0	77.3	82.2	87.6	0.75
McAlpine:								
Utility-Based High	55.2	65.3	70.2	76.8	84.4	90.5	98.4	0.97
Utility-Based	55.2	65.3	68.6	74.4	80.4	85.2	91.2	0.84
NAAQS	55.2	68.8	82.3	89.1	96.2	103.1	110.3	1.16
Clear Skies	55.2	54.7	72.8	76.3	80.1	83.9	87.6	0.77
Modified Clear Skies	55.2	71.0	77.2	83.5	90.1	96.4	103.0	1.05

TABLE 6-8 (cont)

Projected Lock Traffic Demand (Millions of Tons)

Project/Scenario	2000	2010	2020	2030	2040	2050	2060	Annual % Change 2000-60
Cannelton:								
Utility-Based High	54.1	66.1	71.7	78.6	86.7	92.8	101.2	1.05
Utility-Based	54.1	66.1	70.0	76.1	82.4	87.3	93.6	0.92
NAAQS	54.1	71.5	85.1	92.4	100.0	107.1	114.8	1.26
Clear Skies	54.1	58.0	72.8	76.5	80.5	84.2	88.2	0.82
Modified Clear Skies	54.1	74.1	80.9	87.7	94.8	101.5	108.7	1.17
Newburgh:								
Utility-Based High	63.0	75.1	83.7	93.2	103.3	110.2	121.0	1.09
Utility-Based	63.0	75.1	81.3	89.0	97.0	102.4	110.2	0.94
NAAQS	63.0	85.4	100.0	109.6	119.4	126.9	136.7	1.30
Clear Skies	63.0	69.8	83.0	86.9	91.4	95.4	99.7	0.77
Modified Clear Skies	63.0	87.7	96.3	105.5	115.0	122.1	131.5	1.23
Myers:								
Utility-Based High	72.0	85.1	97.9	110.4	125.5	131.5	145.5	1.18
Utility-Based	72.0	85.1	94.4	104.6	115.6	119.8	129.5	0.98
NAAQS	72.0	93.6	106.1	117.2	129.0	135.7	146.5	1.19
Clear Skies	72.0	77.6	88.6	93.0	98.4	103.2	107.8	0.68
Modified Clear Skies	72.0	94.3	102.0	112.6	124.0	130.3	140.7	1.12
Smithland:								
Utility-Based High	81.4	95.3	110.3	124.9	143.1	148.9	165.3	1.19
Utility-Based	81.4	95.3	105.9	118.0	130.7	134.5	145.6	0.97
NAAQS	81.4	105.8	119.9	133.2	147.4	152.0	164.6	1.18
Clear Skies	81.4	88.8	101.6	106.4	112.1	116.4	121.0	0.66
Modified Clear Skies	81.4	106.9	115.4	127.5	141.0	145.3	157.2	1.10
L/D 52: 1/								
Utility-Based High	91.8	107.5	121.2	134.7	148.9	158.4	172.4	1.06
Utility-Based	91.8	107.5	118.7	130.3	142.1	150.2	160.9	0.94
NAAQS	91.8	114.1	129.7	141.9	154.7	163.7	175.4	1.09
Clear Skies	91.8	98.5	113.1	120.6	128.5	135.1	142.1	0.73
Modified Clear Skies	91.8	116.2	127.2	138.7	151.2	159.9	171.3	1.05
L/D 53: 1/								
Utility-Based High	85.3	93.2	103.0	112.5	123.0	132.0	142.0	0.85
Utility-Based	85.3	93.2	102.1	111.1	120.5	128.5	137.1	0.79
NAAQS	85.3	92.0	102.8	108.0	117.1	124.0	132.1	0.73
Clear Skies	85.3	85.8	93.5	100.9	108.8	115.3	122.2	0.60
Modified Clear Skies	85.3	93.4	103.5	107.5	116.6	123.5	131.5	0.72

SOURCE: USACE Waterborne Commerce Statistics and LRD Navigation Planning Center

1/ Forecasts made with Ls/Ds 52 & 53 in place. Both will be replaced by Olmsted L/D in 2011.

to meet the requirements of existing or proposed environmental regulations. The utility-based forecasts reflect the outlook of the utilities themselves. The remaining forecasts are based on the solution of linear programming procedures that determine utility plants' least-cost combinations of inputs, including coal by type, in a market context. Since most of the forecasts were arrived at independently and since considerable coal switching takes place in some of the forecasts, the forecasts can align quite differently at the locks. For example, the high forecast at one lock may not be the high forecast at another.

Forecast growth rates tend to be the highest for the lowermost of the upper Ohio projects and for projects on the lower river. This reflects an anticipated increased interest in Northern Appalachian coal and Illinois Basin coal on the part of the utilities, as well as increases in the movement of western coal on the ORS. Utilities are expected to include more Northern Appalachian and Illinois Basin coal in their mixes because these coals are lower cost and because scrubbing becomes more widespread through time. The lowest growth rates occur at the uppermost Ohio River locks and locks on the middle river. The lower growth rates at the uppermost Ohio River locks reflects increased usage of local coals by plants on the Monongahela and the upper Ohio. Lower growth rates for projects in the middle river reflects diminished interest in Central Appalachian coals resulting from reduced availability and resulting increased production costs for these coals.

6.6 INDUCED TRAFFIC DEMAND

On the Ohio River, the Upper Ohio locks at Emsworth, Dashields and Montgomery are substantially constrained when compared to other projects on the river.
Each of these projects has a 600'x110' main chamber and a 360'x56' auxiliary chamber. All of the remaining projects on the Ohio River have at least one 1200'x110' lock chamber and normally have one 600'x110' auxiliary lock chamber. The small size of the chambers at the Upper Ohio projects produces high delays during operational periods. The high number of lockage cycles required at these locks has also resulted in substantially more down time at the Upper Ohio projects than at other main stem projects.

In light of this situation, a special traffic survey was conducted with the purpose of identifying traffic that could be induced by waterway improvements on the Upper Ohio segment. This survey was conducted by analysts at TVA. The induced traffic survey began with an analysis of available commodity traffic data, including regional waterway and rail traffic. From a list of 513 companies, 30 high-potential shippers were ultimately identified. The 30 high-potential shippers were contacted during the course of field interviews. Following the interviews, a list of potential shipments was constructed and movements totaling 954,000 tons were identified that were considered to be representative of the type and volume that could be expected to be induced to use the waterway by improvements on the Upper Ohio. A listing of the traffic is provided in **Table 6-9**

TABLE 6-9

Potential Induced Traffic

Commodity	Tonnage
Coal & Coke	25,000
Chemicals	80,000
Ores & Minerals	40,000
Iron & Steel	379,000
All Other	430,000
TOTAL	954,000

* additional details on the induced traffic are provided in Attachment 4, Addendum 3 of the Economics Appendix see page 11 of that document.

SECTION 7
SYSTEM MODELING, INPUTS, CALIBRATION AND OUTPUTS

7.1 INTRODUCTION

Cost-benefit analysis is used to identify the System Investment Plan (SIP) that maximizes net benefits (benefits minus costs) -- the NED plan. As the analytical technique implies, half of the analysis is the SIP cost estimates themselves and the other half is the benefit estimates.

The engineering team provided normal O&M, scheduled maintenance and scheduled improvement costs for the mainstem projects included in this analysis under three different proposed maintenance plans and several different new construction improvement plans. The Ohio River Navigation Investment Model (ORNIM) used engineering reliability and economic input data to estimate unscheduled repair costs under the three maintenance plans and several new construction improvement plans analyzed. The scheduled maintenance costs, scheduled improvement costs, normal O&M costs, and unscheduled repair costs collectively comprise the total project costs for each system investment alternative analyzed.[1]

Benefit estimates are a product of the system benefit analysis, which is conducted within the supply and demand framework discussed in Section 1, Introduction. The ORNIM is the system model used to keep track of all the traffic interactions and to estimate the NED benefits and navigation impacts for each of the structural and nonstructural project investment alternatives being evaluated in the SIP. It is an annual model that can be described as a spatially-detailed, partial equilibrium model. It is used to determine equilibrium traffic system transportation rate savings while optimizing investment alternatives.

On inland waterways, structural measures include new lock construction, construction that modifies existing structures (lock extensions), and small-scale investments like mooring cells, all of which improve lock throughput. Nonstructural measures, such as n-up/n-down lockage policies and the use of helper boats, can improve system throughput and encourage more efficient use of the existing infrastructure. ORNIM is able to evaluate and identify a broad range of structural and nonstructural alternatives that yield the optimum combination of capacity enhancements and nonstructural investments for the Ohio River.

[1] Random minor closure costs are also considered in developing total project costs. These costs are explained in Section 8.

The remainder of this section describes the development and structure of ORNIM, its inputs and the results of model calibration. **Attachment 1, Ohio River Navigation Investment Model**, presents a much more detailed discussion of ORNIM and its inputs.

7.2 THE SYSTEM MODEL

7.2.1 Model Development and Structure

ORNIM is based on a long history of model development within the Corps. The Tow Cost Model (TCM) and the Equilibrium Model (EQ), which had their beginnings in the 1970s, served as a starting point for ORNIM [*1*]. ORNIM takes advantage of additional and more refined data, in combination with state-of-the-art computer software, hardware, and computational algorithms, to move to a new frontier of navigation modeling. ORNIM allows users to do analyses not possible with earlier generation models, e.g. optimal selection and timing of a large number of potential river system improvements.

ORNIM was developed as a spatially-detailed partial-equilibrium model, which incorporates the following assumptions: (i) demand for individual movements, provided exogenously, is perfectly inelastic; (ii) willingness-to-pay for individual river movements is equal to the exogenously given least-cost alternative rail rate; (iii) supply of rail for individual movements is perfectly elastic at the exogenously given rail rate; and (iv) equipment idled during closure incur no cost. Empirical evidence on demand elasticity and willingness-to-pay[2] suggests that these assumptions are reasonable. In the short-run, individual movement demand appears fairly inelastic to rates and in the long-run, decisions to move cargo by water depend partly on river rates, and partly on other supply logistics and environmental and energy policies. Appropriately, the demand for waterway movements is exogenous to ORNIM as well; and the Corps' recent scenario-based demand approach enables the analysis of mode and source switching.

ORNIM is composed of three modules – the Waterway Supply Demand Module (WSDM), the Lock Risk Module (LRM), and the Optimal Module (OM) (see **Figure 7.1**). WSDM utilizes detailed information about the Ohio River network (a total of 56 locks with details about river sectors and nodes), towboat/barge operations (numerous tow types and barge configurations with different costs), lock operations, and cargo forecasts (nine commodities with some 31,000 potential movements per year) to estimate annual equilibrium traffic. LRM uses engineering inputs (e.g. reliability estimates, component hazard functions, and repair protocols) to determine the probabilities of unplanned closures for each lock for each year. Optimization identifies the optimal set of investment options (e.g. construction, rehabs, and maintenance) at each lock for a 60-year horizon.

7.2.2 Model Description

It is important to understand the function of each module and then to understand the process for combining the functions into an analytical process. The innovation of ORNIM is not only a more modern and efficient version of standard functionality, but it also

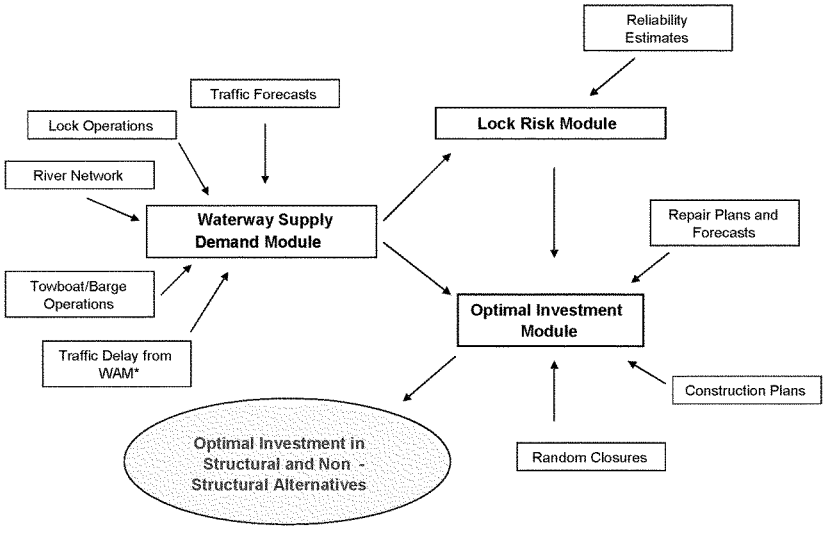
[2] See Attachment 7 Willingness to Pay for Water Transportation in the Ohio River Basin by Larry Bray and Chris Dager at TVA and Mark Burton at Marshall University.

leverages of these new capabilities into a new process for developing and assessing system investment plans.

7.2.2.1 Waterway Supply Demand Module (WSDM)

WSDM determines equilibrium waterway traffic levels under a given system configuration and forecast-scenario for each year in the analysis period, taking into account scheduled lock closures in the system. The first task of WSDM is to develop least-cost waterway shipping plans. WSDM computes the towing costs and determines the cost-effective tow configuration needed to transport each annual port-to-port commodity movement on the waterway network, honoring a set of towing and operating characteristics. Since shipping plans can contain multiple configurations over different sections of the river with configuration changes allowed at pre-specified re-fleeting points, ORNIM uses a dynamic programming approach to optimize the shipping plan. Once each movement's shipping plan and cost characteristics are determined, WSDM solves for equilibrium traffic levels. Equilibrium is reached when every movement fully assigned to the waterway has a lower cost-per-ton water routing than overland, resulting in a positive rate-savings, while every movement fully assigned to overland routing has a lower cost-per-ton than by water. Thus no single movement can lower its transportation costs by changing modes. Solving for equilibrium traffic is a difficult computational problem, requiring an iterative approach because the cost of shipping a movement by water depends on the aggregate traffic level at each lock on the movement's route. The process of equilibration eventually converges to a solution.

FIGURE 7-1
The ORNIM Systems Model



* Traffic delay is input into WSDM through a family of tonnage-transit curves developed by the Waterways Analysis Model (WAM) – see Attachment 2, Capacity Analysis.

WSDM reads WAM developed tonnage-transit time functions for each lock. Tonnage-transit curves are developed for normal operating conditions (no closures) and for multiple closure durations anticipated over the analysis period. WSDM also reads scheduled maintenance closure data specifying the number and type of closures scheduled to occur at each lock chamber during the year. The scheduled maintenance closures are based on engineering analysis of the maintenance requirements of each structure and are alternative specific. WSDM uses the tonnage-transit curve data and the scheduled closure data to calculate the change in each movement's lock transit cost relative to the base-year rate-savings. Base-year rate-savings were developed from detailed transportation rate analysis. If the change in the towing costs exceeds the base-year rate-savings, the movement's waterway rate-savings erodes and becomes negative, and the model assumes the movement will divert to the overland mode. Determining equilibrium traffic flows begins by ranking the movements in descending order according to their base-year waterway rate-savings. The model then adds movements to the system, each time adjusting the lock traffic totals and determining if the movement will have a positive savings on the waterway. Once the end of the list is reached, the procedure begins at the top again this time removing or adding each movement to maximize the movement's savings. Some movements may have its tonnage split, achieving a net zero savings. The iterative process continues to go through the list of movements until a pass through does not produce a change. At this point equilibrium is reached (every movement that can move at a transportation savings over the all-overland alternative mode is moving via waterway).

WSDM produces equilibrium traffic and transportation rate savings limited by congestion costs associated with scheduled maintenance. The model uses average costs and average rate-savings such that the equilibrium achieved reflects the profit-maximizing actions of individuals and is not a social optimum because individual profit-maximizing behavior does not reflect the impact that one shipper's use of the system has on other shippers using the system. The equilibrium recognizes that individual shippers will not restrict waterway usage to the socially optimum level, but will continue to expand waterway volumes to the level at which their average towing costs equal their average rate-savings. This occurs because each individual carrier pays only its own average cost for moving on the waterway system, not the true marginal costs, which includes congestion costs imposed on others. The equilibrium traffic and associated waterway transportation costs are inputs to the Optimization Module.

7.2.2.2 Lock Risk Module (LRM)

To capture the economic consequences of structural reliability differences between alternatives, engineering hazard functions and event tree information for the major components of each lock chamber (gates, valves, electrical system etc.) are connected to ORNIM through the LRM. The hazard function gives the probability of failure of the component by year given that it has not yet failed and is a function of component age and/or usage (lock traffic). Given a failure from the hazard value, the event tree specifies degree of failure and its consequences in terms of closure duration, repair cost, and resulting reliability. A component fix may require multiple years of investment and multiple closures to implement. Full discussion of component hazard values and event trees is contained in **Attachment 3 Project Maintenance Analysis**.

LRM estimates the probability of each potential closure in each year of a component's life. Given the hazard functions and event tree information for each component considered in the system, the LRM uses Monte Carlo simulation to produce: i) expected repair costs by year and by component for each lock and chamber; and ii) the occurrence probability and duration of each unscheduled closure by age and use of the component. The closure occurrence probabilities allow the Optimization Module to calculate the transportation cost impacts of unscheduled closures. In addition the Optimization Module adds in the expected repair costs for each alternative analyzed.

7.2.2.3 Optimization Module (OM)

The Optimization Module systematically compares each project's investment permutations[3] and timing, selects the optimal investment strategy at each project and summarizes the results. To calculate the costs and benefits for a single investment option, the appropriate WSDM runs are gathered and adjusted for increased transit times caused by unscheduled closures (information passed from LRM). The transportation costs are then merged with expected repair costs (from LRM), scheduled maintenance costs and construction costs to determine the total costs associated with the investment permutation.

Investment strategies are developed from a set of maintenance/improvement alternatives. Underlying all investment strategies are the use of non-structural navigation improvements like industry self help and the appropriate lock operating policy during closure. The concept of an alternative is flexible in ORNIM and can be generally defined as a change to the waterway system which affects the transit time at a lock or locks. Alternatives can add, remove, or replace components and locks; change maintenance plans; change the lock transit curves; change the movement set; and change the waterway network (re-fleeting points, link capacities, tow size etc.). Multiple alternatives for a lock or set of locks can be linked together and the implementation of an alternative can begin any time within a user-specified window. Each alternative is associated with a year-by-year investment cost stream.

The flexibility in how the alternative can be defined provides a powerful modeling tool; however, calculating the resulting savings is a complex process. The complexity prevents the model from using a standard optimization approach. Instead, the optimization module builds a tree of alternatives, branching at each decision point, to efficiently calculate the net value of various paths through the selection and timing of alternatives. Each node in the tree represents a configuration of the waterway system in a particular year. The savings and costs for that year are estimated by combining the results of WSDM and LRM runs under different closure scenarios.

System equilibrium traffic is determined in WSDM given scheduled closures and their affect on transit times. When a solution set where every movement that can move with a transportation-rate-savings is found, the solution set is fixed. To determine the effects of unscheduled closures, LRM closure probabilities and durations are applied to the solution set and the increase in lock transit times leads to an adjustment in the transportation rate-savings for the solution set. The solution set movements are not allowed to divert off the waterway (switch transportation mode on-the-fly), even if they become

[3] Project investment permutations include all possible combinations of component repair, replace, rehab and new construction options.

negative rate-savers. For marginal shippers, it may have been better to have shipped overland, but the mode decision was made using expected transportation times (including scheduled closures) rather than actual transportation times (including unscheduled closures). In other words, the model assumes in the short-run, that modal choice is limited and that there is "little reaction time between the actual movement of goods and transportation decisions." It should be noted that in the development of the tonnage-transit curves, when scheduled and unscheduled closures are both simulated, the WAM re-schedules some shipments around the closure reflecting observed shipper behavior.

The efficient management of the model allows the analyst to quickly analyze investments under different assumptions (e.g. forecast scenarios). For the ORMSS, with sixteen projects, one thousand and six tonnage-transit curves, a total of one-hundred forty-seven components described with engineering reliability information, five traffic forecast scenarios and 31,503 unique movements, the management of even one investment permutation becomes unmanageable without an automated process.

7.3 MODEL INPUTS

ORNIM requires a considerable amount and variety of input. Model inputs can be grouped into five categories: i) infrastructure characteristics, ii) system operation characteristics, iii) movement characteristics, iv) reliability characteristics, and v) investment options. The inputs and their calibration results are briefly discussed in the following paragraphs.

7.3.1 Infrastructure Characteristics

Infrastructure characteristics include:

- Network data specifying the topology of the inland waterway network and the characteristics of its constituent locks, ports, reaches, and other components that affect towing operations and costs.
- Tonnage-transit curves describing the relationship between the average transit time per tow and the aggregate traffic level at a lock (transit time includes both lockage processing and delay) for a normal operational situation and under various closure durations.
- Vessel data specifying the classes of towboats and barges used for towing operations as well as the costs to industry of owning and operating the equipment.

ORNIM has the capability of storing various versions of the waterway network to represent different system configurations needed for analysis. The waterway network is represented as a sequence of nodes connected by links. ORNIM uses a specific nomenclature to define the various elements of the waterway network. Elements include river segments, sectors, links, junctions, ports, locks, and bends. The amount of network detail depends on the geographic scope of the study. The SIP network contains more detail of the Ohio River mainstem and less detail for the tributaries.

The lock nodes represent traffic constraint points on the waterway network and correspond to actual navigation structures where tows enter a chamber in which they are

raised or lowered in order to pass from one pool level to the next. The most important attribute of a lock is its tonnage-transit time relationship which is used to estimate its physical tonnage capacity[4]. Lock transit time has two components – lockage time and delay time. Given a specified tonnage, ORNIM looks up the tonnage on the tonnage-transit curve and pulls off the expected average transit time to use in its cost calculations.

Another type of data included in the infrastructure characteristics of the network is the cost of towboats and barges used to transport cargo on the waterway network. ORNIM uses data on towing equipment operating costs and physical characteristics to calculate waterway line-haul costs. Increasing waterway line-haul cost decreases base transportation rate savings.

7.3.2 System Operation Characteristics

System operation characteristics include:

- Fuel tax assumptions
- Congestion fees
- Construction budget

Operation characteristics include the inputs necessary to analyze certain cost-recovery options and to analyze construction budget constraints. Cost recovery options include fuel taxes, lockage fees and river fees. The current inland waterway fuel tax is 24.43 cents per gallon where it's been since 1995.

Congestion fee analysis is required by Corps planning guidance for all feasibility lock improvement studies requesting authorization. Although a detailed analysis of congestion fees has not been conducted for this study a general analysis of traffic management alternatives was completed and some preliminary determinations are presented in Section 9 of this Appendix.

ORNIM does not yet have the capability to constrain investment with a construction budget. Future plans are to modify the Optimization Module to identify an optimal set(s) of investment alternatives given a budget limit.

7.3.3 Movement Characteristics

Movement characteristics include:

- Commodity data specifying the commodity groups and their transportation characteristics
- Shipment data specifying the origin, destination, commodity group, annual tonnage, barge type, barge loading, and other characteristics of existing or projected port-to-port commodity movements
- Base transportation-rate savings (movement willingness to pay)

[4] In LRD, the Waterway Analysis Model (WAM) is the tool used to develop tonnage-transit time curves and a project's capacity.

A list of movements, existing and forecast traffic demand, is the main driving force of the model. Most of ORNIM's processing is directed toward determining and costing transportation resources needed to satisfy the movement requirements of moving commerce from point A to point B at a transportation-rate savings. The characteristics of the commodity being moved have an effect on shipping costs. Some commodities have a higher value than others. Hundreds of specific commodities are shipped on the mainstem. For modeling purposes, commodities are aggregated into classes with shared commodity values and shipping characteristics. These classes are: 1) Coal, 2) Petroleum Products, 3) Crude Petroleum, 4) Aggregates, 5) Grains, 6) Chemicals, 7) Ores and Minerals, 8) Iron and Steel, and 9) All Other. Coal and aggregates comprised over 70 percent of mainstem traffic in 2003. Coal, aggregates and petroleum products comprised almost 78 percent of mainstem traffic in 2003.

Movement data includes origin and destination port docks, commodity and barge type, tonnage shipped, barge loadings, waterway and alternate mode transportation rates, and a dedication factor to indicate the percentage of barges involved in the movement that will return empty even if a back-haul opportunity exists.

Forecasting future demand on the mainstem is far from certain. As a result, traffic forecast scenarios are developed based on different economic growth and legislative policy assumptions. The effects of these assumptions on waterway improvement benefits can be analyzed.

7.3.4 Reliability Characteristics

To capture reliability differences between different system configurations (alternatives) ORNIM compares lock chamber maintenance plans (scheduled closures) and probabilistic component reliability closures (unscheduled closures). Engineering reliability analysis provides hazard functions that describe probabilities of component failure and event trees that describe the costs and consequences associated with a failure. Unscheduled repair can alter a planned maintenance schedule. Engineering cost-closure information is used by ORNIM to optimize maintenance repair plans, time component replacement or indicate the need for new construction.

7.3.4.1 Hazard Functions

The reliability of a lock component is defined probabilistically by the Engineering Team. Engineering component models are loaded with the various strength measurements of each component along with the expected future loads for each component. A number of life-cycles are simulated and the timing and frequency of failures are recorded and tabulated as shown in the example shown in **Table 7-1**. The result is a "hazard function" (shown in **Figure 7-2**) which is the probability of failure in a specific year given that the component has not failed up to that year.

Component hazard values are projected out into the future and hence depend on expected future traffic levels and component utilization. Closures elsewhere in the waterway system can affect utilization levels. To account for this uncertainty in the economic analysis, five different forecast scenarios are considered and hazard values are

calculated for a low, medium and high utilization levels. ORNIM interpolates between hazard values depending on the forecast being used.

7.3.4.2 Event Trees

The hazard function only identifies a probability of failure and does not indicate the magnitude of the failure or the consequences. Failure consequences are described in event trees (**Figure 7-3**). The initial branch in the event tree (fail or not fail) is determined by the hazard function and is year specific. Given a failure, the level of failure is based on the branch probabilities for the different levels of failure.[5] The repair, in terms of closure duration and cost, is also described for the specific degree of failure. The event tree provides probabilities of different degrees of failure and the repair consequences.

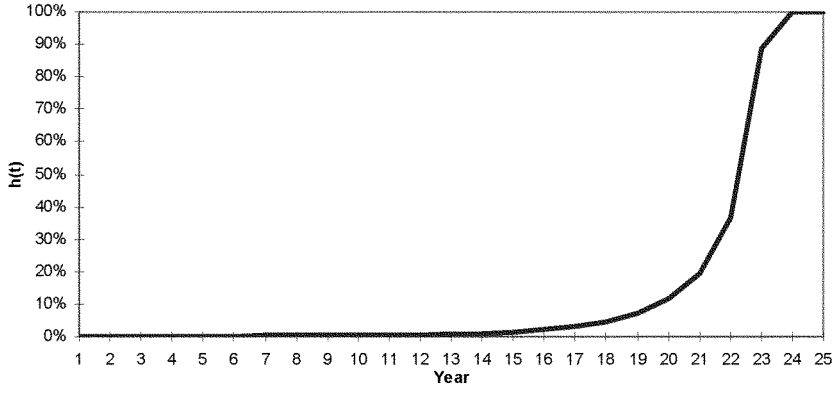
TABLE 7-1
Hazard Function Development

Yr	Failures		Cumulative Survivors	f(*t*) (or pdf)	F(*t*) (or CDF)	R(*t*) = 1 – F(*t*)	h(*t*) =	
	Count	Cumulative					(R(*t*-1)-R(*t*)) / R(*t*-1)	No. failures yr (*i*) / No. of survivors up to year (*i*)
0	0	0	528	0.00000	0.000	1.000	0.00000	0.00000
1	2	2	526	0.00379	0.004	0.996	0.00379	0.00379
2	2	4	524	0.00379	0.008	0.992	0.00380	0.00380
3	2	6	522	0.00379	0.011	0.989	0.00382	0.00382
4	2	8	520	0.00379	0.015	0.985	0.00383	0.00383
5	2	10	518	0.00379	0.019	0.981	0.00385	0.00385
6	2	12	516	0.00379	0.023	0.977	0.00386	0.00386
7	2	14	514	0.00379	0.027	0.973	0.00388	0.00388
8	2	16	512	0.00379	0.030	0.970	0.00389	0.00389
9	2	18	510	0.00379	0.034	0.966	0.00391	0.00391
10	2	20	508	0.00379	0.038	0.962	0.00392	0.00392
11	2	22	506	0.00379	0.042	0.958	0.00394	0.00394
12	2	24	504	0.00379	0.045	0.955	0.00395	0.00395
13	3	27	501	0.00568	0.051	0.949	0.00595	0.00595
14	4	31	497	0.00758	0.059	0.941	0.00798	0.00798
15	5	36	492	0.00947	0.068	0.932	0.01006	0.01006
16	7	43	485	0.01326	0.081	0.919	0.01423	0.01423
17	9	52	476	0.01705	0.098	0.902	0.01856	0.01856
18	12	64	464	0.02273	0.121	0.879	0.02521	0.02521
19	17	81	447	0.03220	0.153	0.847	0.03664	0.03664
20	24	105	423	0.04545	0.199	0.801	0.05369	0.05369
21	34	139	389	0.06439	0.263	0.737	0.08038	0.08038
22	49	188	340	0.09280	0.356	0.644	0.12596	0.12596
23	72	260	268	0.13636	0.492	0.508	0.21176	0.21176
24	107	367	161	0.20265	0.695	0.305	0.39925	0.39925
25	161	528	0	0.30492	1.000	0.000	1.00000	1.00000
				1.00000				

NOTES - F(t) must be zero or greater but can never go above 1.0. R(t) must start at 1.0 and can never go below 0.0. h(t) must be greater than 0.0 but can never get greater than 1.0.

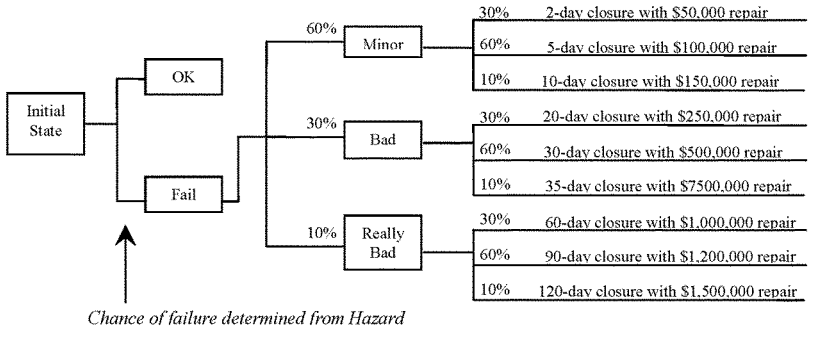
[5] Failure mode Degree of failure branch probabilities can vary by year.

FIGURE 7-2
Example Hazard Function Curve



The level of failure generally determines the repair response. Minor failures generally require a minimal repair with a short-duration chamber closure. The probability of failure in the subsequent years might remain the same (the hazard function is not changed). A moderate failure generally requires a larger repair with a longer duration chamber closure. This repair might increase the reliability of the component, but not to the reliability of a new component. In this case, the hazard function might be re-set to *n*-years earlier. For a catastrophic failure, a high repair cost with a long duration closure is usually the consequence. In the case of catastrophic failures, the repair typically calls for replacement of the component, in which case, the hazard function is set to 100-percent reliable[6].

FIGURE 7-3
Example Consequence Event Tree



[6] While no component will be 100 percent reliable, once it is replaced as part of a new project / major rehabilitation / component replacement, it is assumed to be reliable given regular maintenance. New components are assumed to be designed to current standards and with applicable standards and with applicable safety factors. A chance of significant failure is remote and would occur far into the future if at all.

7.3.5 Investment Options

Investment options specify possible investments that can be made and their effects on reliability, forecasts, and shipping characteristics. The investment can specify different investments that can affect a change in component reliability, a move to a different forecast, or a switch in shipping characteristics.

7.4 MODEL CALIBRATION / VALIDATION

ORNIM is a behavioral as well as a predictive model: it requires validation that it is capable of replicating observed shipper behavior and system operating characteristics. Waterborne Commerce Statistics Center (WCSC) data provides annual origin-to-destination barge flows by commodity; however, information on tow-size, towboat utilization, and empty return characteristics is not available for individual movements. These characteristics are recorded by the Lock Performance Monitoring System (LPMS) at each of the locks. LPMS data provides vessel fleet characteristics of the flow. The goal of calibration is to determine if the WSDM generated shipping plans produces tow characteristics at each lock similar to historical tow characteristics. The shipping plans determine the cost characteristics of each movement used to assess the effects of increased shipping times in the waterway system.

As already mentioned, the first task of WSDM is to develop least-cost waterway shipping plans for each annual port-to-port commodity movement on the waterway network honoring a set of towing and operating characteristics. Calibration is a sequential process involving several iterative steps. At each step, certain static components of the model's waterway system towing and operating characteristics are adjusted or fine-tuned, the model is exercised, and specific results are compared with corresponding target values from LPMS data for the designated baseline or calibration year. The calibration process is designed to ensure that the relevant measures match their corresponding target values as best as possible.

7.4.1 Dedication Factor Calibration

A total barge count (loaded and empty) is necessary to accurately model waterway congestion. WCSC data provides detailed loaded barge information but empty barge data is not as readily available. For this reason, the modeling process has a method for generating empty barge flows based on loaded barge flows and this process needs calibrated to yield accurate estimates of total barge flows.

The first step in calibration is to determine the empty barge flows in the system. Empty barges are determined from a "dedication" factor assigned to each annual port-to-port commodity movement, which specifies how dedicated the barges are to the movement. If the dedication factor is 0, when the loaded trip is complete, the barges are free to move another movement. If the dedication factor is 1, the barges are totally dedicated to the movement, meaning that when the loaded trip is complete, the barges are required to move empty back to the movement's origin. If the dedication factor is between

0 and 1, the barges are partially dedicated, and the dedication factor indicates what portion of the set of barges must make the trip back to the movement's origin empty.

The dedication factor is assigned in a WSDM pre-processor using two linear programming problems. In the first the objective is to minimize the deviation from the target number of empty barges at each navigation project, given the path that each of the movements is taking. Solving this, the program determines a total "best deviation from targets" value. In general, there may be several assignments of dedication factors to movements that will achieve this best deviation. Tanker barges are more likely to be dedicated than are hopper barges, due to the nature of the cargo that they carry. The second linear program attempts to maximize the dedication factors for the tanker classes of barge, and minimize the dedication factors for the hopper classes of barges. Using this objective and the added constraint that the total deviation is equal to the "best deviation" found in the first linear program, the model determines a final setting of the dedication values. These values are then stored.

7.4.2 Tow-size and Towboat Utilization Factor Calibration

The second component of the calibration process is the calibration of the tow-sizes and the average towboat horsepower levels. If the limits set were based solely on the physical limitations of the river, WSDM would tend to produce shipping plans with larger tows than historically observed. To account for the factors encouraging shippers to use slightly smaller tows, WSDM uses another calibration routine to generate a set of tow-size limitations that produce tows comparable to the historically observed fleet at each lock.

There are a number of factors that limit the size of a tow. Each towboat has a limit on the number of barges it can tow, regardless of where in the river system it is working. There are tow-size limits by barge type for each sector of the river that limit the total number of barges in a tow on that river segment. And finally, there are towboat capacity utilization factors that are characterized by towboat and river segment that restrict a towboat's towing capacity. Adjusting the tow-size limits and towboat capacity utilization factors affects the size of the tows that are used, as well as the type of towboat selected for a particular movement.

Because the determination of the shipping plan is a complex process, an analytic procedure similar to that used to set the dedication factors could not be used. Instead, the calibration of the tow-sizes and horsepower is done in an iterative process, by making a small change to a tow-size limit, running WSDM with the changed value, and noting whether the result is closer to the targets than before the change. This is done for every barge type on every river segment. A similar process determines the effect of changing the towboat capacity utilization factors for each towboat on each river segment. Once all of the possible changes have been examined, the calibration program chooses the change that will result in the most improvement, changes that value in the database, and then begins again. When the improvements are negligible, the program stops.

Once the three calibration parameters are determined, validation against LPMS targets can be accomplished. **Figures 7-4 and 7-5** display the summary report showing the 2001 calibration/validation results of ORNIM.

FIGURE 7-4
ORNIM 2001 Calibration/Validation

Lock	Tons/Barge			Transit Time			LoadedBarges		
	Model	Target	%	Model	Target	%	Model	Target	%
Emsworth	1,343	1,341	0.1%	151	151	0.0%	15,985	16,007	-0.1%
Dashields	1,349	1,344	0.4%	114	114	0.0%	16,336	16,394	-0.4%
Montgomery	1,402	1,397	0.4%	115	115	0.0%	17,824	17,893	-0.4%
New Cumberland	1,512	1,502	0.7%	74	74	0.0%	22,117	22,261	-0.6%
Pike Island	1,541	1,532	0.6%	72	72	0.0%	27,338	27,502	-0.6%
Hannibal	1,577	1,569	0.5%	74	74	0.0%	32,330	32,489	-0.5%
Willow Island	1,590	1,582	0.5%	83	83	0.0%	30,190	30,341	-0.5%
Belleville	1,600	1,592	0.5%	74	74	0.0%	31,812	31,976	-0.5%
Racine	1,601	1,593	0.5%	91	91	0.0%	32,239	32,404	-0.5%
Byrd	1,645	1,636	0.6%	93	93	0.0%	36,322	36,516	-0.5%
Greenup	1,668	1,645	1.4%	105	105	0.0%	44,190	44,808	-1.4%
Meldahl	1,687	1,658	1.7%	154	154	0.0%	38,362	39,015	-1.7%
Markland	1,648	1,615	2.0%	115	115	0.0%	33,943	34,634	-2.0%
Mcalpine	1,645	1,606	2.4%	141	141	0.0%	33,425	34,236	-2.4%
Cannelton	1,595	1,569	1.7%	106	106	0.0%	34,915	35,503	-1.7%
Newburgh	1,604	1,584	1.3%	100	100	0.0%	40,854	41,355	-1.2%
Myers	1,650	1,628	1.4%	238	238	0.0%	45,438	46,065	-1.4%
Smithland	1,648	1,636	0.7%	48	48	0.0%	51,772	52,161	-0.7%
L/D 52	1,655	1,650	0.3%	197	197	0.0%	57,167	57,194	0.0%
Olmsted	1,665	1,651	0.8%	29	29	0.0%	49,326	49,599	-0.6%

FIGURE 7-5
ORNIM 2001 Calibration/Validation

Lock	Tows			Horsepower			Tow Size		
	Model	Target	%	Model	Target	%	Model	Target	%
Emsworth	3,764	4,526	-16.8%	2,062	1,741	18.4%	6.7	5.5	21.8%
Dashields	3,946	4,147	-4.8%	2,054	1,833	12.1%	6.5	6.2	4.8%
Montgomery	4,280	4,109	4.2%	2,037	2,095	-2.8%	6.5	6.8	-4.4%
New Cumberland	4,081	4,244	-3.8%	2,829	2,924	-3.2%	9.1	8.8	3.4%
Pike Island	5,067	4,726	7.2%	2,776	3,070	-9.6%	8.9	9.5	-6.3%
Hannibal	4,487	4,388	2.3%	3,411	3,372	1.2%	10.8	11.0	-1.8%
Willow Island	3,970	4,004	-0.8%	3,491	3,516	-0.7%	10.9	10.8	0.9%
Belleville	4,206	4,046	4.0%	3,485	3,582	-2.7%	10.9	11.4	-4.4%
Racine	4,275	4,275	0.0%	3,491	3,538	-1.3%	10.9	10.9	0.0%
Byrd	4,751	4,895	-2.9%	3,577	3,657	-2.2%	11.1	10.8	2.8%
Greenup	6,843	6,850	-0.1%	3,443	3,484	-1.2%	11.0	11.1	-0.9%
Meldahl	5,609	5,415	3.6%	3,494	3,831	-8.8%	11.1	11.6	-4.3%
Markland	4,600	5,292	-13.1%	3,666	3,716	-1.3%	11.5	10.1	13.9%
Mcalpine	4,127	5,166	-20.1%	3,724	3,703	0.6%	11.5	9.4	22.3%
Cannelton	4,322	4,638	-6.8%	3,715	3,967	-6.4%	11.6	11.0	5.5%
Newburgh	5,257	5,869	-10.4%	3,872	4,132	-6.3%	12.1	10.9	11.0%
Myers	5,778	5,985	-3.5%	3,849	4,259	-9.6%	11.9	11.6	2.6%
Smithland	6,914	7,384	-6.4%	3,705	4,002	-7.4%	11.6	10.9	6.4%
L/D 52	7,994	9,281	-13.9%	3,514	3,626	-3.1%	11.0	9.5	15.8%
Olmsted	6,679	6,681	0.0%	3,422	4,208	-18.7%	10.8	10.8	0.0%

7.5 MODEL OUTPUTS

ORNIM optimizes investment strategies developed from a set of maintenance/improvement alternatives. The model analyzes engineering reliability, scheduled maintenance, economic traffic forecasts, and lock capacity data to predict system performance. System equilibrium traffic and transportation rate-savings limited by congestion costs associated with scheduled maintenance are outputs of WSDM. The LRM produces expected repair costs and the occurrence probability and duration of each unscheduled closure. The OM calculates transportation cost impacts of unscheduled closures, selects an optimal investment strategy, and summarizes results.

System performance statistics generated by ORNIM include equilibrium tonnage, savings and transit days. These statistics are generated for each of 5 traffic forecast scenarios. Sections 8 and 9 present summary system statistics for each of the maintenance/investment alternatives analyzed. Section 10 presents the recommended system investment plan for the Ohio River mainstem from 2010-2070.

SECTION 8
IDENTIFICATION AND EVALUATION OF THE WITHOUT-PROJECT CONDITION

8.1 INTRODUCTION

The without-project condition (WOPC) is that future condition deemed most likely to exist in the absence of any proposed project(s) or any change in existing authority or public policy. By regulation, the Corps as steward of the inland navigation waterways must make best use of the existing facilities for overall public interest concerns, including economic efficiency, safety and environmental impacts. Accurate description of the most likely future WOPC is important because it is used as the baseline for comparing benefits, costs and net benefits of alternative investments.

8.1.1 WOPC Formulation

Formulation of the WOPC begins with the existing locks and their current performance and structural condition. It involves maintenance of the existing system in the absence of new investment. Any reasonably expected and economically justified nonstructural measure within Corps authority is assumed implemented at the appropriate time. The WOPC includes all operational measures which are routinely employed during periods of congestion. These include the use of helper boats and revised lockage policies to improve project performance and ensure the best use of the existing facilities during main chamber closures. The WOPC also includes all authorized improvements that are either under construction or are pending appropriation. The most likely WOPC will not include any proactive maintenance requiring an investment decision, such as replacing major operating components and major rehabilitations.

8.1.2 Reliability Assessment

The mainstem Ohio River is a system of 20 locks and dams that create a series of navigation pools over the 981-mile length of the Ohio River. Today's system will be reduced to 19 lock and dam projects upon completion of Olmsted L/D and the removal of L/Ds 52 and 53. Specifically, the ORMSS system investment plan (SIP) evaluates the major maintenance, major rehabilitation, and new construction investment needs for 17 of these navigation locks and dams.[1] With existing traffic levels, most Ohio River locks experience high traffic delays when main lock chambers must be closed for routine (scheduled) or emergency (unscheduled) repairs or accidents. Mainstem navigation locks and dams are becoming increasingly unreliable due to age and cycles of use, which is

[1] The authorized Olmsted, Myers auxiliary extension and Greenup auxiliary extension and main chamber rehab are assumed on-line from the beginning of the period of analysis (2010-2070).

manifest in an increasing frequency of lock chamber closures for inspection and repair. Assessing the structural reliability of these structures is an important component of the without-project evaluation. These assessments suggest some locks need more immediate, near term attention than other locks. Of course, a complete evaluation of near term needs at specific locks is influenced not only by their structural condition, but also by expected levels of traffic demand and auxiliary lock capacity. It is important to note that engineering reliability modeling was not performed on navigation dam components in this analysis due to funding and schedule constraints. The primary focus was on the lock components from an engineering standpoint since maintenance closures of these structures can significantly effect traffic, whereas, routine schedule maintenance of dams usually has no effect on traffic delays. It is highly recommended that both navigation dams and all the Ohio River tributary locks and dams have a detailed reliability assessment completed for them as a follow-on action in order to incorporate the entire Ohio River system.

8.2 EXISTING CONDITION

As navigation projects age, component reliability worsens and maintenance requirements and unscheduled closures typically increase. Degradation of lock components can come from fatigue through utilization and/or age (e.g. corrosion). As lock components degrade, the question arises if and when they should be repaired or replaced.

Development of a system WOPC begins with an assessment of existing condition, capacity, and demand; each a key input to the economic modeling. Lock reliability and capacity, traffic, and traffic delays are discussed for all mainstem sites. Ultimately, a lock's performance capability is limited by two factors: i) physical capacity and ii) structural reliability. The former is influenced by chamber dimensions, hydraulic conditions, vessel fleet characteristics, weather conditions, and accident frequencies; while the latter is affected by a given project's structural condition and intensity of maintenance efforts. The capability to process traffic juxtaposed with traffic demand tests a lock's performance. Transit time and lock delay are used to measure lock performance. This subsection describes the existing condition of the mainstem Ohio in terms of project age and reliability, project capacity, and traffic demand and delay.

8.2.1 Project Age and Reliability

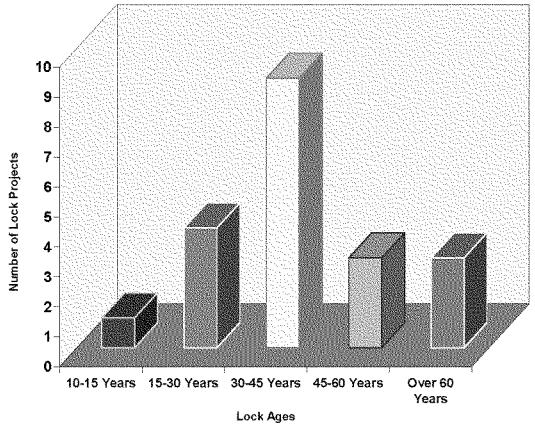
Lock performance is affected by lock availability for service. Availability is reduced due to random minor events like accidents, adverse weather, flow conditions, and maintenance-related closures. Maintenance closures, scheduled or unscheduled, are more likely to be lengthy closures that more dramatically affect lock performance than the random minor closure events which are short duration closures. Age and level of use can act as an indicator of maintenance and rehabilitation needs. **Figure 8-1** shows that six mainstem projects are currently over 45 years old. By 2010, Emsworth, Dashields, and Montgomery (EDM) will each be over 80 years old and nine more locks will be at or near their original design life of 50 years.[2]

[2] EDM were rehabilitated in the 1980s - new miter gates, culvert valves, and re-facing some of the lock concrete structures. These rehabilitations did not address all known structural issues. There are still serious concerns regarding the structural integrity and stability of the concrete structures at these three sites.

The main chamber miter gates at Markland, Meldahl, Greenup, and McAlpine have reached the end of their effective service life (see **Table 8-1)**. They are currently maintained through emergency measures that include inspection dives and dewatering the lock chamber on a much more frequent basis than other Ohio River locks. All gates are operational, however, the physical repair costs and navigation impacts associated with maintaining these gates causes a significant portion of the annual O&M funds to be dedicated to them. This, in turn, means that the backlog of proactive maintenance for other important projects continues to increase. Even with increasing maintenance of these gates, they remain highly susceptible to a catastrophic failure given their current condition and continued high level of use.

Typically, Ohio River main chamber locks are dewatered every 5 years for maintenance and/or inspections. Markland's main chamber is dewatered annually to inspect and repair the gates and Greenup is dewatered every two years. Meldahl is expected to move to a more aggressive maintenance schedule in the near future. Markland has been approved by Corps HQ for new main chamber gates and valves but has not yet been funded.[3] Most major maintenance work at Ohio River lock and dam projects has been deferred until a later date.

FIGURE 8-1
Existing Mainstem Lock Ages



Greenup Locks experienced a costly 34-day unscheduled emergency repair in 2003. Emergency repairs at McAlpine Lock closed the Ohio River completely for 11 days in 2004. Hannibal Locks had an unscheduled total river closure lasting 5 days in November 2005. The Hannibal closure was due to a failure of a load bearing quoin seal on one of the main chamber miter lock gates while the auxiliary chamber was down for scheduled maintenance. Reacting to emergency repairs diverts scarce O&M resources from other

[3] 7 July 2000 Corps Headquarters approved and requested the Assistant Secretary of the Army to include in the program as a new start major rehabilitation.

scheduled maintenance work. Any growth in the maintenance backlog adds risk of costly unscheduled closures for emergency repair to Ohio River navigation infrastructure.

8.2.2 Project Capacity

Lock performance capability is largely determined by lock chamber dimensions, approach conditions, and service availability. The three uppermost Ohio River projects, Emsworth, Dashields, and Montgomery (EDM) each have a main chamber measuring 600' x 110' and an auxiliary lock measuring 360' x 56'. They are the lowest capacity locks on the Ohio River (see **Table 8-1**). Modern fifteen barge tows must double-lock through the main chambers at EDM, while in the auxiliary chambers tows are limited to 5 barges and can only be locked through one barge at a time. Smithland, with the greatest capacity on the river, has twin 1200' x 110' chambers. Once authorized construction is completed, both McAlpine L/D and the new Olmsted L/D (replacing L/Ds 52 and 53) will also have twin 1200' x 110' chambers. Auxiliary lock extensions are authorized but not yet under construction at Greenup and Myers locks. All other locks on the mainstem Ohio have a 1200' x 110' main chamber and a 600' x 110' auxiliary chamber (a configuration commonly referred to as a 1200' and a 600').

Three non-structural measures to improve capacity are part of the existing system and are included in the development of the WOPC. They are: i) helper-boats during a main chamber closure; ii) n-up and n-down lockage policy during main chamber closure; and iii) re-scheduling of shipments during a long duration, scheduled main chamber closure. The use of helper-boats, through an industry self-help program, effectively maximizes the capacity of the small 360' x 56' auxiliaries on the upper Ohio and the 600'x 110' auxiliaries elsewhere.[4] An n-up and n-down lockage policy, when queues exist in both directions, also effectively increases capacity during a main chamber closure. These practices, along with limiting tow sizes to five cuts during a main chamber closure on the upper Ohio, are reflected in lock capacities reported in **Table 8-1**. Some voluntary re-scheduling by industry occurs because of navigation notices mailed out six-months to one-year in advance of the scheduled closure. Industry re-scheduling during a closure serves to re-distribute tows on either side of the closure. Annual throughput, or capacity is unaffected but average delay-per-tow during the closure is lower than it would be otherwise.

8.2.3 Traffic Demand and Delays

Total traffic on the Ohio River doubled between 1968 and 2004[5], when it reached 237.9 million tons. This growth has not been spread evenly along the river. Upper river projects experienced 1.0 to 2.0 percent average annual growth from 1987 to 2004. Mid-river lock traffic growth was more robust, between 2.0 and 3.0 percent. Lower river projects traffic grew the slowest at less than 1.0 percent a year. Much of this is attributable to electric utilities' reaction to the latest round of Clean Air Act Amendments (CAAA). Despite this uneven growth in traffic, Myers, Greenup, and Newburgh locks remain the top three mainstem projects in terms of total traffic among projects with small

[4] The self-help program at EDM includes a restriction on tow sizes to 5 barges per tow.
[5] This is according to WCSC data.

600' auxiliary chambers. **Figure 8-2** displays 2004 tonnage at all the projects with 600' auxiliary chambers. Capacity of a 600' project is around 50 million tons a year. **Figure 8-2** shows where current traffic levels exceed auxiliary capacity at mainstem projects. High delays are experienced at these projects when main chambers close for maintenance or repair.

TABLE 8-1
Ohio River Mainstem Locks - 2004
Age, Chamber Dimension and Capacity, 2004 Tonnage
(Million Tons)

Lock Project	Age	Chamber Dimension		Chamber Capacity			2004 Tonnage
		Main	Auxiliary	Main	Auxiliary	Both	
Emsworth	84	600x110	360x56	39.4	12.6	45.8	18.8
Dashields	76	600x110	360x56	46.5	12.9	51.7	19.7
Montgomery	69	600x110	360x56	43.9	12.9	47.6	20.3
New Cumberland	46	1200x110	600x110	78.5	44.5	132.9	31.5
Pike Island	40	1200x110	600x110	99.5	47.9	151.2	38.9
Hannibal	33	1200x110	600x110	103.1	52.4	152.1	50.1
Willow Island	33	1200x110	600x110	107.5	54.2	155.1	48.1
Belleville	37	1200x110	600x110	114.6	56.3	167.2	51.4
Racine	38	1200x110	600x110	110.5	54.0	151.1	52.3
R.C. Byrd	12	1200x110	600x110	116.3	55.5	151.0	57.8
Greenup	46	1200x110	600x110	113.3	54.3	144.2	64.5
Meldahl	43	1200x110	600x110	116.3	55.5	151.0	55.3
Markland	46	1200x110	600x110	119.0	57.1	160.5	50.1
McAlpine	44	1200x110	1200x110	120.0	123.0	225.5	52.8
Cannelton	34	1200x110	600x110	124.0	59.0	162.1	56.9
Newburgh	30	1200x110	600x110	135.6	61.7	169.8	67.2
J.T. Myers	30	1200x110	600x110	137.3	63.6	170.6	67.9
Smithland	26	1200x110	1200x110	143.4	132.9	264.4	77.0
Olmsted[1/]	0	1200x110	1200x110	na	na	na	95.0

1/ Currently under construction, 2004 tonnage is for L/D 52

Delays are a function of a project's capacity, fleet utilization, reliability, and traffic demand. Delays during normal traffic operations typically range from less than 10 to not more than 75 minutes at mainstem locks. **Figure 8-3** displays average lock delays from 1994-2004 at mainstem projects. Excessive delays develop when the main chamber is closed at any of these locks. Delays are most severe on the upper Ohio (EDM) and at the high traffic locks below Byrd L/D. In 2003, a 34-day unscheduled closure of Greenup's main chamber caused a 43 hour average delay per tow and cost industry over $42 million in additional transportation and other logistical costs. This is not surprising given that the physical capacity of the small auxiliary chamber at Greenup is estimated at 54 million tons, an annual ability overwhelmed by demand in 2003 that reached almost 63 million tons. These delays dramatically increase tow transit times and, therefore, tow transit costs.

FIGURE 8-2
2004 Traffic at Ohio River Mainstem Projects with 600' Auxiliary Chamber

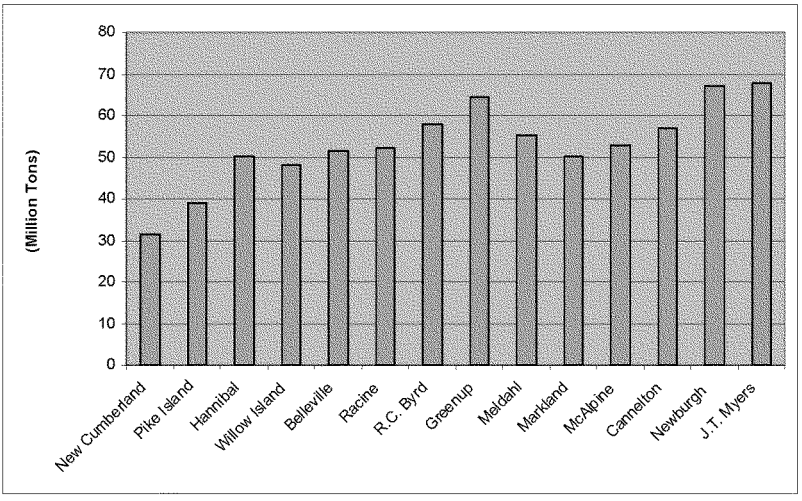
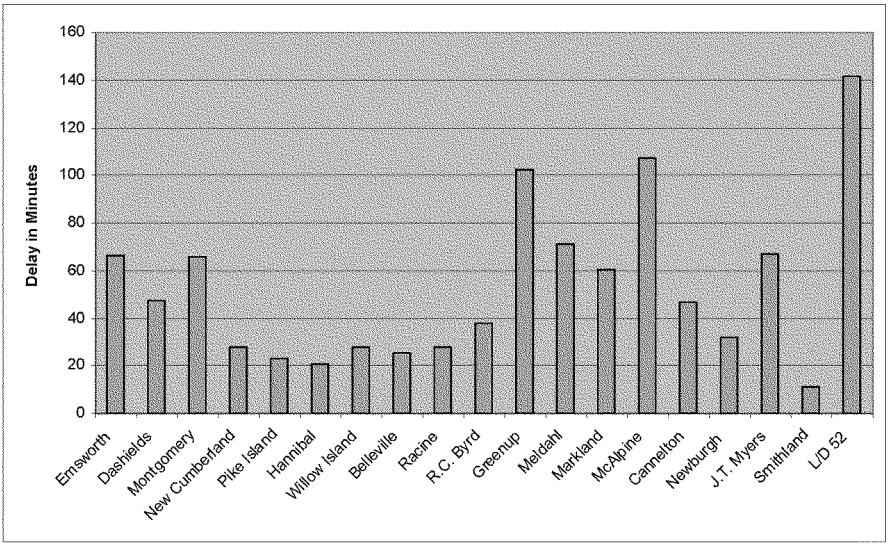


FIGURE 8-3
Ohio River Mainstem, Average Lock Delays per Tow, 1994 – 2004



8.3 MAINTENANCE AND OPERATIONAL MEASURES

Maintenance and its effect on the performance of aging locks is a key concern to sustainable navigation. The efficient operation of the existing locks and dams is an important consideration and this is especially true during times when the main chamber is closed for maintenance and all traffic is processed through the smaller auxiliary chamber.

Three different maintenance plans were developed and analyzed for the SIP. They include reactive maintenance, advanced maintenance or component replacement, and rehabilitation maintenance (bundled components) that exceed the major rehab monetary threshold as set forth in USACE guidance, currently $10.6 million for inland navigation projects. Both advanced component replacement and major rehabilitation require an investment decision and, because of this, were not considered included in the WOPC. Instead, these two proactive maintenance plans are considered to be with-project alternatives and are evaluated by comparison to the WOPC like all other new investment decisions. In the absence of new investment, a reactive maintenance plan where components are repaired or replaced "after they fail", is assumed to be the base maintenance plan for the WOPC and is the standard against which the alternatives are measured. Maintenance and investment costs, reactive maintenance, and operational measures associated with the WOPC are described in the following sub-sections.

8.3.1 Maintenance and Investment Costs

Component level reliability evaluations were conducted on 17 mainstem projects[6] to estimate probable project performance and maintenance requirements from 2010 to 2070. A detailed discussion of engineering reliability modeling is presented in the **Engineering Appendix** and greater detail on the reactive, advanced, and rehabilitation maintenance plans is presented in **Attachment 3 Project Maintenance Analysis** of the Economics Appendix.

Reactive maintenance and each alternative investment analyzed contains normal (or routine) O&M costs, scheduled lock maintenance costs, scheduled dam maintenance costs, unscheduled lock repair costs, random minor costs, and scheduled lock improvement costs at each project throughout the study period. All Federal maintenance and investment costs are described below:

- Normal O&M or routine operation costs are the annual fixed costs to operate the project with some incidental maintenance that doesn't impact traffic. Corps normal O&M policy operates a project as efficiently as possible in the absence of any repair or maintenance that improves project reliability.[7]
- Scheduled Lock Maintenance costs are costs related to periodic or cyclical chamber inspections that close a chamber, including any some relatively minor maintenance/repair costs. Cyclical maintenance procedures typically do not address

[6] No reliability work was done on the authorized Olmsted, Greenup and Myers auxiliary chamber.
[7] Normal (or routine) O&M is a fixed-cost to operate the project and includes labor, utilities, mowing the grass, and basic project supplies.

the long term failure probabilities (reliability) associated with fatigue/fracture and the end of useful design life and therefore it is assumed that cyclical maintenance does not have a significant affect on the overall reliability of the structures[8]. However, it is noted that schedule maintenance does help keep the major features in working order and operating as originally designed. The reliability analysis was carried out for the situation where the components are no longer cost effective to repair.

- Scheduled Dam Maintenance costs are attributed to maintenance and rehabilitation of dam components (dam gates, operating machinery, concrete piers, etc.) This maintenance is critical to sustainable navigation but does not typically require a lock chamber closure because the repair fleet can tie up outside the river wall keeping them open to traffic. Reliability modeling was not performed on dam components because it was decided by the overall ORMSS team that the effort should initially focus on the lock components since their performance affects traffic. Since much of the work done under ORMSS was developmental and state-of-the-art, there was not enough time or funding to analyze the dam components for their reliability. As noted earlier, it is highly recommended that follow-on funds be provided to model Ohio River dam components and the tributary projects so the entire system is analyzed in the same manner. In lieu of dam reliability analysis, deterministic scheduled dam maintenance costs are estimated from engineering judgment and are the same in all maintenance and improvement plans analyzed. Dam maintenance costs are included in the analysis to account for the full cost of operating the system. It is noted that some information developed from recent Ohio River dam major rehabilitation studies (Emsworth and J.T. Myers) has been included within the ORMSS analysis from a deterministic standpoint.
- Unscheduled Lock Repair costs are estimated from reliability modeling that determines when to repair or replace major lock components over a 60 year period of analysis. ORNIM is run to estimate unscheduled repair costs for each maintenance plan.
- Random Minor closures are separated into two categories. These are random minor closures that require maintenance and those that require no physical repair costs. The random minor closures with repair costs are intended to reflect lock closures for routine maintenance or testing. This is typically for on-site or contract personnel and not the large repair fleet. Random minor closures without repair costs are for things such as debris in lock, tow malfunctions, accidents, etc.
- Scheduled Lock Improvement costs include already authorized improvements at Greenup and J.T. Myers. J.T. Myers is already in construction and Greenup is in the final stages of design for its initial construction contracts. These costs are included in the WOPC because the investment decisions have already been made. Scheduled lock improvements involving future investment decisions include economically justified individual lock component replacements, chamber rehabilitations, lock extensions, and lock replacements are new investment decisions and are treated as alternatives to be compared to the WOPC. Scheduled lock improvements involving future investment decisions are discussed in Section 9 - Identification and Evaluation of Alternative Investment Plans.

[8] This is mainly due to the fact that we are looking at failure modes that are associated with fatigue and fracture of critical members (miter gates and valves in particular)

8.3.2 Reactive Maintenance

Under reactive maintenance, components are fixed or replaced after they perform unsatisfactorily. The Engineering Team analyzed 20 components (**Table 8-2**) at each mainstem lock chamber; however, the reliability of some components (lock walls, approach walls, etc...) was found to be highly reliable and did not require a follow-on economic analysis. The product of this detailed analysis is a series of site and component specific reliability models that were used to calculate expected component failures through time, estimate the cost and type of repair required, and determine whether the failure caused a chamber closure. This information was used by ORNIM to calculate the unscheduled repair/replace costs and industry costs associated with an unanticipated lock closure under reactive maintenance plan. The reactive maintenance plan as developed in the WOPC, serves as a baseline against which to compare more proactive maintenance plans and structural improvement investments.

Under reactive maintenance, normal O&M is performed, along with scheduled cyclical maintenance. Unscheduled lock repairs and their costs are estimated from reliability modeling. Repairs designed to correct the cause of a failure are made at the time of failure and not deferred through a short-term repair. Scheduled lock improvements for the mainstem include only the authorized improvements at Greenup and J.T. Myers. No lock rehabilitation occurs, though individual components may be replaced upon failure. Scheduled dam maintenance, based upon engineering judgment and experience from recent major rehabilitation studies, is included in project costs.

TABLE 8-2
Mainstem Lock Components
Reliability Analysis

Main Chamber		Auxiliary Chamber
Upper Guard Wall		Upper Guide Wall
River Wall		Land Wall
Lower Guard Wall		Lower Guide Wall
Middle Wall		Middle Wall
Miter Gates (upper & lower)		Miter Gates (upper & lower)
Miter Gate Machinery		Miter Gate Machinery
Culvert Valves		Culvert Valves
Culvert Valve Machinery		Culvert Valve Machinery
Hydrauilic Systems		Hydrauilic Systems
Electrical Systems		Electrical Systems

8.3.3 Operational Measures Currently Implemented

During normal operation, with both chambers open, delay is not usually a problem and project capacity is sufficient to handle traffic efficiently at all mainstem projects throughout the 60-year period of analysis. During normal operation, tows are handled on a

first-come-first-served basis.[9] When a main chamber must be closed, tows must use the auxiliary chamber, which is smaller at all sites except Smithland L/D. At the lower and upper Ohio projects, where traffic demand exceeds the capacity of the smaller auxiliary chambers, delays occur. During main chamber closures, a number of effective supply-side measures designed to improve efficiency and reduce delay are currently employed at the locks and are included in the base-level WOPC analysis. These include lockage sequencing, tow-haulage, and helper boats. Traffic demand management measures, such as Notices to Navigation Interests[10] are used to reduce lock congestion by providing waterway users advance notice of scheduled closures. Notices to Navigation Interests allow towing companies and their customers to reschedule traffic to the extent possible around scheduled main chamber outages. The operational effect of rescheduling shipments in response to scheduled closures is captured in future traffic-delay relationships in the analysis through the tonnage-transit curves developed by the WAM, but the additional costs incurred by shippers to reschedule around a closure are not included in this analysis. These operational and other measures are discussed below.

8.3.3.1 Notice to Navigation Interests: Industry Coordination

Two years before a scheduled closure, the Corps sends a notice to waterway users announcing its intent to close a lock and the expected dates of closure. The notice includes anticipated delays during the closure, expressed as significant or minor, and the operational policies to be in effect. Around six months before the scheduled closure, the Corps and affected towing companies meet to finalize procedures for operating during the closure. Even with low levels of delay expected, special accommodations, such as cut limits, are required because the auxiliary chambers are typically one-half the size of the main chambers. If major delays are expected, the announcement will also state that tows have priority in lockage over recreational craft. This is an effort to provide industry information to better manage traffic during a scheduled closure.

8.3.3.2 Lockage Sequencing : N-up, N-down Lockage Policy

This strategy (to minimize delays at locks that develop queues) involves locking a given number (N) of tows in the same direction, then allowing the same number to lock through from the opposite direction. Lock sequencing takes advantage of the efficiency of proceeding with several successive "turnback" style lockages rather than running tows through in alternate directions when queued on either side of the lock. Use of this strategy has been proven to lower delays over a first-come-first-served policy at virtually zero cost. This is a supply management measure that has the effect of increasing capacity during closure. Lock sequencing is modeled at all mainstem projects during any main chamber closure and an optimal n-up/n-down strategy is developed.

Typically, as queues develop above and below a project during a main chamber closure, a 3-up and 3-down lockage policy is used to most efficiently and equitably pass traffic. The actual n-up and n-down policy used depends on the queue sizes and is under the discretionary authority of the lock master.

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[9] FIFO – first-in-first-out

[10] Industry receives Notices to Navigation Interests from the Corps well in advance of a scheduled maintenance closure.

8.3.3.3 Helper-Boats: Industry Self Help

The use of helper boats complements the n-up/n-down lockage policy. Helper boat operations are a collaborative effort between industry and the Corps. Due to traffic levels and fleet size, industry implements a helper boat policy any time a main chamber is closed on the Ohio. The industry "self help" operation significantly reduces lockage times for multi-cut lockages and typically works as follows: the last towboat to arrive at a congested project in the direction opposite of an on-going lockage operation will disconnect from its barges and move up to the lock, where it serves as a "helper boat" by assisting the tow locking through the project by extracting un-powered cuts of barges from the lock chamber. It will then move the barges to a re-fleeting site away from the project so that reconstruction of the tow does not interfere with lockage operations. Industry self help is provided to each tow until all barges have moved through the lock. To be effective, the policy requires tows queued in both directions above and below the project. This is another supply-side measure that enhances capacity during a closure and is modeled at each mainstem project during a main chamber closure.

8.3.3.4 Tow Haulage

Tow haulage units are relatively low-cost pieces of equipment that can be used to expedite the two-cut lockage process when there are no other towboats to pull the un-powered cut out of the chamber. The units are not necessary at 1200' lock chambers as double cuts through those chambers are not permitted. There are two principal types of tow haulage systems: permanent and portable. Permanent units consist of rail tracks located directly alongside the chamber on top of the walls and a moveable tie-down unit that moves on the rails. The un-powered barges are tied to the moveable tie-down unit by a cable, and the unit moves along the rails to pull the barges out of the chamber. Portable systems consist of two winches that are anchored atop the upstream and downstream guide walls. The winches "crank" the cable, pulling the barges out of the chamber. The second set of barges, which are powered by a towboat, can then lock through the chamber unassisted. Upon completion of the second lockage, the first and second cuts are reconnected along the guide wall.

Permanent tow-haulage systems are only installed at the main chambers of Emsworth, Dashields, and Montgomery (EDM) where the main chambers are 600' in length compared to 1200' at all other mainstem projects. Double lockages through these main chambers are a common occurrence even during normal times. Additional permanent tow-haulage units are not considered necessary at any of the other lock chambers that are 600' long. At the 600' auxiliary chambers, such units would have their greatest need during closures of the main chambers. However, during those times queues generally develop at both sides of the lock providing a steady supply of tow boats and industry self-help is a much better measure to pull unpowered cuts from the auxiliary chambers as that process is faster than tow haulage. Permanent tow haulage units are not considered appropriate at the 360' x 56' auxiliary chambers at EDM because these chambers can only lock one barge at a time and oftentimes (during main chamber closures) tows require two to five cuts. Portable units are considered sufficient at these other small lock chambers.

8.3.3.5 Industry Adjustments During Main Chamber Closures

The towing industry also makes adjustments during main chamber closures to maintain as normal a delivery schedule as possible. Industry adjustments include reducing the number of empty barges, increasing barge loadings, shipping around closures, working off stockpiles, or shipping by other routings. These adjustments are accounted for in the LPMS data used to develop the closure related tonnage-transit curves.

8.3.3.6 Other Measures

Other measures intended to reduce commercial lockage delays include real-time lock reports on the Corps web page, mooring cells, and interchangeable miter gates. Information contained in the lock reports is updated every few hours and includes the number of tows waiting in queue and river flow conditions at each facility. Coordination with industry is conducted on a regular basis, not just during those times prior to an extended main chamber closure. These low-cost measures have proved useful and are accepted by the navigation industry.

Mooring cells are structures that provide vessels a place to tie off while waiting for their turn to lock through. Without such facilities, the towboats must either push into the riverbank, which can cause erosion and damage to the shoreline vegetation, or wait out in the currents of the river, which wastes fuel. Preliminary evaluations cited in the J.T. Myers and Greenup Locks Improvements – Interim Feasibility Report concluded that there is no potential for economic benefit from adding mooring cells at any lock and dam. However, mooring cells were considered appropriate for EDM from an environmental perspective and were modeled as a feature of the without-project condition (WOPC).

The Great Lakes and Ohio River Division (LRD) has begun to implement a system where miter gates can be changed out quickly, significantly reducing chamber downtime for miter gate maintenance and repair. There are two components to the miter gate quick change-out system (MGQCS): i) a derrick crane with gate-lifting capability and ii) spare gates at the projects. Currently, the MGQCS is only partially implemented. LRD has the gate lifter crane but not any spare gates. For this reason and the fact that considerable investment is required, a MGQCS is not included in the WOPC.

8.3.4 Operational Measures Not Currently Implemented

Price-related traffic demand management measures are not currently used on the mainstem. Using lock scheduling to reduce delays that occur during the normal course of using the Ohio River mainstem is not currently practiced and has not been thoroughly evaluated. A preliminary research effort into the physical practicality and economic feasibility of lock scheduling is underway as part of this study. Results-to-date can be found in **Attachment 5 Traffic Management** at the end of this appendix. The ultimate outcome of this effort and how far it is developed depends on future ORMSS SIP funding. This future effort is beyond the scope of this study.

8.4 SYSTEM-WIDE BASE-LEVEL WOPC

Historically, LRD lock improvement studies have assumed unconstrained funding for major maintenance and major rehabilitation in developing the WOPC. LRD optimized the WOPC in navigation feasibility studies through a mixture of non-structural and structural measures like component replacement and chamber rehabilitation not requiring congressional authorization. The Corps has authority for major rehabilitations and advanced component replacements but recent history shows the Administration considers some component replacements and all major rehabilitation as a new start and the Administration is not currently budgeting for new starts (e.g. Markland Major Rehabilitation).

Therefore, for purposes of this analysis, any maintenance beyond fixing-after-failing is assumed to require an investment decision and is not included in the base-level WOPC. Proactive maintenance plans like advanced maintenance and chamber rehabilitation require an investment decision and therefore, in this analysis, will be treated as with-project alternatives along with other structural improvements.

Given recent funding levels, a reactive maintenance future seems most likely. Accordingly, a base-level reactive maintenance WOPC will serve as the basis to compare more aggressive maintenance plans and structural improvement investments. The use of appropriate non-structural and operational measures and the assumption of authorized projects in-place are also part of the base-level WOPC.

The WOPC includes the following authorized Ohio River improvements:

- Olmsted L/D – Olmsted L/D is modeled throughout the period of analysis[11]. Since this investment is under construction, no federal costs are included. The locks and approach walls at Olmsted are completed and the dam is currently under construction.

- Myers auxiliary chamber extension – J.T. Myers auxiliary lock extension is under construction. J.T.Myers is included in the WOPC as a twin 1200' x 110' project. Federal costs for the chamber extension are included.

- Greenup auxiliary chamber extension and main chamber rehab – Greenup is included in the WOPC as a twin 1200' x 110' project with a rehabbed main chamber. Federal costs for the rehab are included.

- McAlpine lock replacement – The new lock chamber at McAlpine became operational in 2009.

[11] Period of analysis is 2010-2070

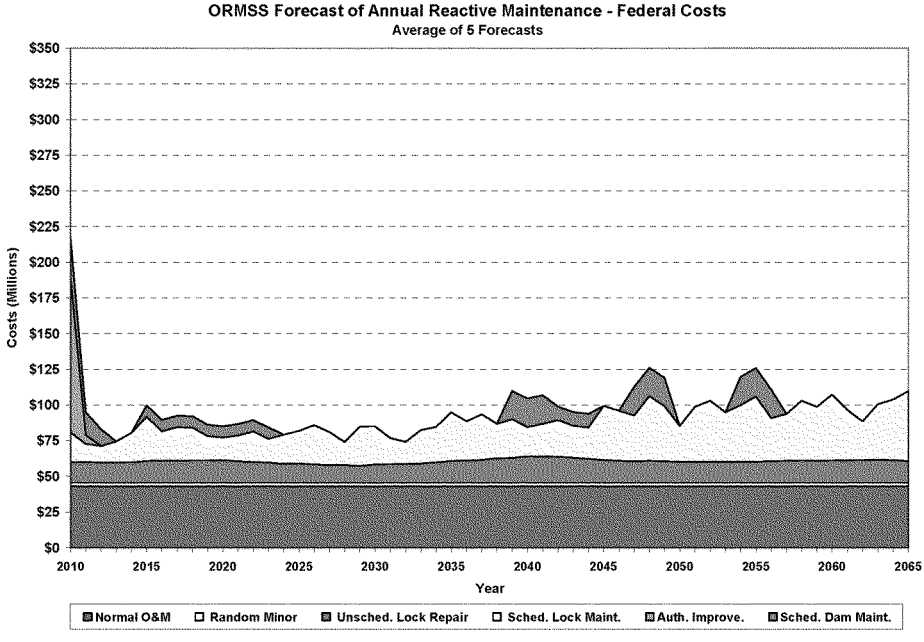
8.5 EVALUATING REACTIVE MAINTENANCE

The reactive maintenance plan can be described in terms of its Federal costs and its associated cost impacts on navigation. ORNIM uses engineering reliability data to predict emergency repair/replacement closures on an annual average basis. These unscheduled closures reduce system capacity and cause navigation delays that reduce system transportation rate savings by increasing waterway costs.

8.5.1 System Costs

ORNIM was run at each project to estimate expected unscheduled repair/replace costs under each of the five different traffic forecast scenarios. The unscheduled repair costs are added to other Federal maintenance costs to develop total system costs. **Figure 8-4** shows forecast reactive maintenance funding needs. Overall, this analysis shows an average annual expenditure of around $99.8 million is required to sustain navigation on the Ohio River from 2010-2070 with a reactive maintenance strategy and continued degradation of the major operating components.

FIGURE 8-4

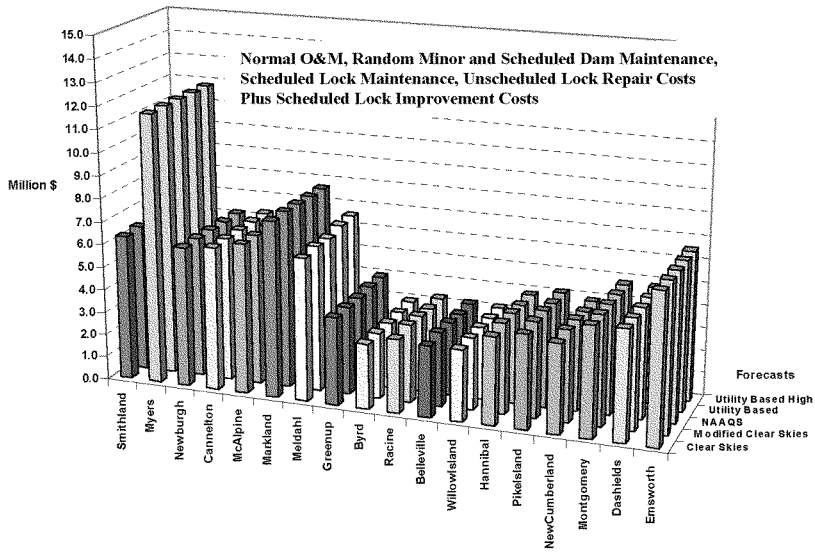


The Corps has a legal mandate to provide efficient navigation on the Ohio River. In the long run, a reactive maintenance strategy will result in more frequent scheduled and unscheduled closures than more proactive maintenance strategies. Such a maintenance strategy will not sustain the efficient level of navigation on which our stakeholders depend. In recent years, the Corps has been funding Ohio River O&M budgets at a level below the base-level reactive maintenance strategy described in this study. This alone will indicate to some the need for increased major maintenance on the Ohio River.

Figure 8-5 displays average annual Federal costs for the reactive maintenance strategy by project and by traffic forecast. The bar graph combines normal O&M, random minor, scheduled dam costs, scheduled lock maintenance costs, unscheduled lock repair costs and lock improvement costs. The scheduled lock maintenance costs and unscheduled lock repair costs represent potential cost savings that can be realized with more aggressive maintenance (upfront component replacement or major rehabilitation). The scheduled lock improvements are the authorized J.T. Myers and Greenup improvements. High reactive maintenance needs are seen on the upper and lower Ohio projects.

Section 4 of **Attachment 3 Project Maintenance Analysis** displays each project's component-level, expected transit costs and repair costs for each traffic forecast scenario with a reactive maintenance strategy.

Figure 8-5
Reactive Maintenance
Average Annual Project Costs
(2010-2070, 5 1/8%, FY 03$)

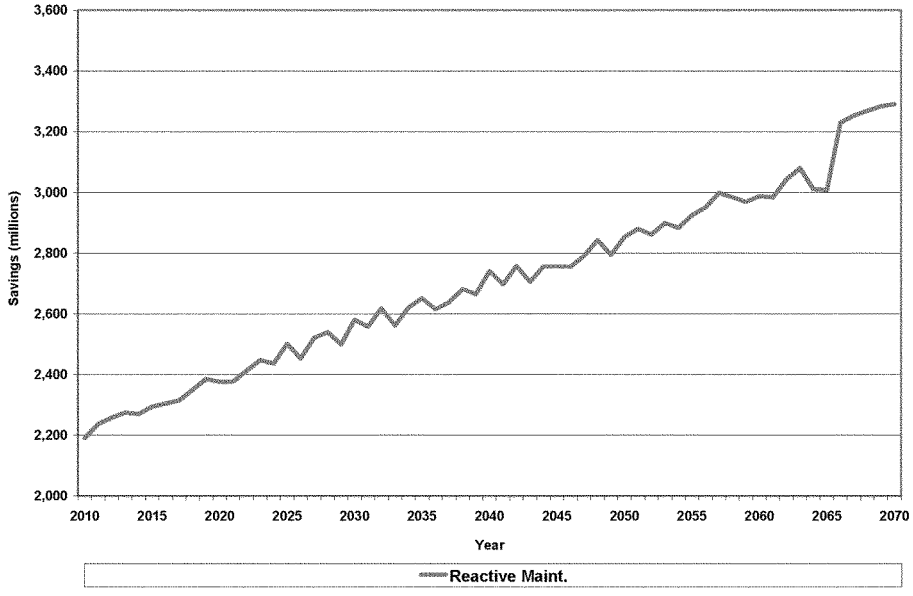


8.5.2 System Benefits

The primary benefit for Federal investment in the inland waterways is the collective transportation cost savings for barge shipment over the least-costly alternative routing. The benefit is referred to as transportation rate savings. Corps regulation recognizes transportation rate savings or cost reduction as a national economic development (NED) benefit.

In ORMSS, NED benefits are calculated from equilibrium waterway traffic transportation rate savings net of any reduced transportation savings from congestion or delay due to unscheduled repair closures. **Figure 8-6** displays system transportation savings averaged over all 5 traffic forecast scenarios for the base-level reactive maintenance WOPC. Average annual system NED benefits are $2.46 billion from 2010-2070.

FIGURE 8-6
Reactive Maintenance System Transportation Savings
Average of 5 Forecasts



8.5.3 System Statistics

Table 8-3 summarizes average annual expected system waterway costs and benefits of a reactive maintenance strategy at each mainstem project for each of the five traffic forecast scenarios. Total system benefits are equilibrium system NED transportation rate savings net of any transportation losses caused by congestion or delay due unscheduled repair closures. Average annual system benefits range from $2.25 to $2.46 billion.

Total system costs are the expected average annual Federal and Trust Fund expenditures needed to maintain Ohio River navigation infrastructure under the reactive maintenance strategy. The Federal costs represent the costs to the Federal government to maintain, repair, or improve the navigation projects under the reactive maintenance policy. Scheduled maintenance costs are what the Federal government pays for the scheduled cyclical maintenance of the mainstem projects. Scheduled improvement costs in the reactive maintenance strategy are the Federal and Trust Fund costs of authorized mainstem projects (Greenup and J.T. Myers). Unscheduled repair costs are the Federal costs associated with the unscheduled repair and replacement of lock components under the reactive maintenance strategy. Normal O&M is the day-to-day recurring cost to the Federal government to staff and supply the project regardless of the project's ability to accommodate any traffic – things like on-site labor, utility costs, cutting grass, etc. Average annual system costs range from $99.0 to $100.1 million. Net benefits range from $2.15 to $2.36 billion.

TABLE 8-3
Reactive Maintenance*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Reactive Maintenance Benefits					
Equilibrium Waterway Savings	$2,328.6	$2,493.5	$2,476.0	$2,536.4	$2,580.5
Reduced Savings from Unscheduled Repair	($75.8)	($119.8)	($124.1)	($107.7)	($120.3)
Total System Benefits	**$2,252.8**	**$2,373.7**	**$2,351.8**	**$2,428.7**	**$2,460.1**
Reactive Maintenance Costs					
Scheduled Lock Maintenance	$ 23.1	$ 23.1	$ 23.1	$ 23.1	$ 23.1
Scheduled Dam Maintenance	$ 6.9	$ 6.9	$ 6.9	$ 6.9	$ 6.9
Scheduled Lock Improvements*	$ 5.8	$ 5.8	$ 5.8	$ 5.8	$ 5.8
Unscheduled Lock Repair	$ 14.0	$ 15.1	$ 15.0	$ 14.7	$ 15.0
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$99.0**	**$100.1**	**$100.0**	**$99.8**	**$100.1**
Net Benefits	**$2,153.8**	**$2,273.6**	**$2,251.8**	**$2,328.9**	**$2,360.1**
BCR	**22.7**	**23.7**	**23.5**	**24.3**	**24.6**

** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include the authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11.*

SECTION 9
IDENTIFICATION AND EVALUATION OF ALTERNATIVE INVESTMENT PLANS

9.1 GENERAL

This section identifies and evaluates increasingly proactive maintenance plans and alternative improvement plans that address the navigation problems and needs of the Ohio River. The proactive maintenance plans include advanced maintenance where individual components can be replaced before failing and chamber rehabilitation where individual component replacements can be bundled into a major rehabilitation. The major rehabilitation category must meet the costs current threshold of $10.6 million for inland navigation projects, as outlined in USACE guidance. The alternative improvement plans include new 600' and 1200' chambers to replace the auxiliary chambers at Emsworth, Dashields and Montgomery. Each alternative requires an investment decision and therefore is considered a with-project alternative. The alternatives, as presented in this study, build on each other with each successive alternative incorporating cost effective investments of the previous alternative.

Evaluation of alternative investment plans will ultimately identify an optimal system mix of site-specific maintenance alternatives, non-structural improvements, and large-scale structural alternatives for each traffic forecast scenario.

9.2 OPTIMIZING COMPONENT MAINTENANCE

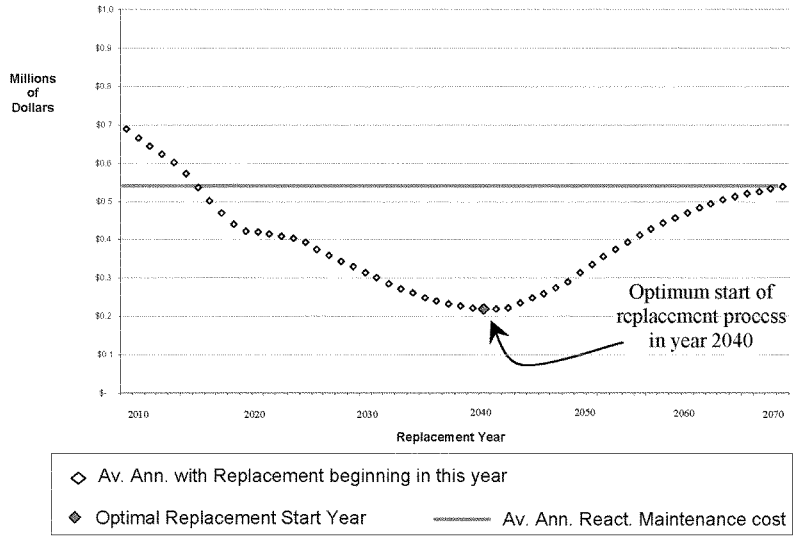
The ORNIM Lock Risk Module (LRM) simulates each year's expected repair costs and closure probabilities for each lock component analyzed. ORNIM's Optimization Module (OM) then calculates the annual expected equilibrium waterway savings (benefits) and total Federal reactive maintenance (RM) costs. This defines the expected net benefits for the reactive maintenance plan.

If the likelihood of a lock component's failure is high enough and assuming a scheduled component replacement has less consequence (i.e. lower cost and shorter chamber closure) than an unplanned replacement, it is better to replace a component before it failed. Unfortunately, it is impossible to determine precisely when a failure will occur. The next best option is to estimate the expected annual reactive maintenance costs of repair and transportation impacts over the planning period and compare them to the cost of proactive replacement. The least-cost alternative (reactive maintenance vs. replace in the 1st year vs. replace in the 2nd year, etc.) is the optimal maintenance plan for a component.

ORNIM compares the expected cost for the reactive maintenance plan with the costs for proactive component replacement in various years. If for example, the component replacement cost in 2020 is being calculated, the expected reactive maintenance costs up through 2019 are accumulated, the probability of the components survival in 2020 is calculated and the expected up-front replacement cost is calculated[1]. This amortized cost stream with a 2020 replacement is compared to the amortized RM cost stream. The least-cost alternative is the optimal maintenance alternative.

Figure 9-1 uses a hypothetical set of main chamber miter gates to illustrate an average annual RM cost ($0.54 million) relative to average annual miter gate replacement costs for each year in the period of analysis. In this example, repair, replacement, and transportation costs can be minimized with a proactive miter gate replacement starting in 2040. In this example, the optimum replacement means that a contract for gate construction occurs in 2040 and actual gate replacement occurs in subsequent years. In this case, a scheduled 30-day closure is modeled in 2041 to replace the upper gates and another scheduled 30-day closure is modeled in 2042 to replace the lower gates. All components were modeled this way; optimum replacement timing represents the year the replacement process starts. Gates and valves are the only components requiring two subsequent years for replacement; all other components are modeled as only needing one.

FIGURE 9-1
Hypothetical Main Chamber Miter Gates
Reactive Maintenance vs. 2010-2070 Replacement



[1] If the component's event tree contains a replacement of the component, there is a chance that the component is replaced before the scheduled up-front replacement date. In these simulations the scheduled replacement is canceled and replacement costs are not double counted.

Navigation projects, however, are composed of many components. Determination of optimal replacement timing of each component is a critical step, but it may not indicate the best maintenance alternative for the project. Combining individual component replacements might offer savings in mobilization and de-mobilization costs and result in fewer chamber closures. Also, a large enough bundling of component replacements might eliminate enough collective reactive maintenance costs to be economically justified even if the up-front replacement of the individual components not being justified. This type of condition analysis of individual components and bundled components is useful in formulating possible chamber rehabilitation or replacement strategies and can result in an overall least-cost maintenance strategy for the Ohio River which could consist of a combination of reactive maintenance, advanced maintenance (component replacement), and chamber rehabilitation alternatives.

9.3 ALTERNATIVES EVALUATED

9.3.1 Advanced Maintenance (Component Replacement)

The advanced maintenance strategy allows for a component to be replaced before it fails. A planned, up-front component replacement can minimize the adverse navigation impacts of an unscheduled, emergency repair. Before advanced maintenance can be fully formulated at a project, optimal individual component replacements must be determined. Optimal individual component replacement represents a piecemeal maintenance strategy which can be more efficient than reactive maintenance. It is considered a viable stand-alone alternative although there might be more efficient "bundles" of component replacements. The bundling of components can lead to a major rehabilitation strategy and this is discussed in the next sub-section.

The engineering team evaluated approximately twenty lock components and component systems at each mainstem project for reliability purposes, however on average, only ten were identified at each project as critical enough to warrant detailed economic analysis since many of the components were found to be highly reliable for the conditions evaluated as a part of ORMSS. For each of these components and/or component systems, ORNIM was used to calculate the expected costs of maintenance and repair and the additional transportation costs associated with the delays from the associated maintenance and repair closures. The amortized reactive maintenance costs are compared to up-front component replacement scenarios to determine if replacement is economically justified and if so, the optimal timing for the upfront replacement.

The advanced maintenance alternative combines reactive maintenance with economically justified component replacement. **Tables 9-1** through **9-5** show the year for beginning the recommended component replacement process and reactive maintenance (RM) schedules for each project and traffic forecast scenario. *The gray shaded cells represent components found to be highly reliable during the engineering reliability analysis and were not modeled in ORNIM.* RM in a cell represents reactive maintenance, which is the same thing as fixing the component after failing, and the numbers in the cells represent the year which optimizes the start of the proactive component replacement process.

TABLE 9-1
Advanced Maintenance
Scheduled Component Replacement
Forecast Scenario – Clear Skies

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	RM	29	39	24	-	10	16	-	55	53	32	30	12	17	-	-	-	-
Gate Machinery	RM	18	RM	15	RM	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	16	15	15	30	36	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	38	10	10	RM	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	15	15	15	RM	15	27	-	24	10	10	10	RM	15	RM	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	RM	RM	RM
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	13	12
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	11
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	55	-	-	-	-	RM	10	-	-	-	-	-	RM	RM	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	58	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 9-2
Advanced Maintenance
Scheduled Component Replacement
Forecast Scenario – Modified Clear Skies

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	27	37	24	-	10	12	-	53	38	28	29	10	14	-	-	-	-
Gate Machinery	RM	10	15	22	RM	28	20	-	RM	RM	20	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	10	15	15	30	10	RM	-	RM	RM	20	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	22	37	10	10	RM	-	-	50	-	RM	RM	-	-	-	-	-
Electrical	RM	10	15	15	RM	10	10	-	10	20	10	23	RM	15	15	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	17	RM	38
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	51	-	-	-	-	RM	10	-	-	-	-	-	65	52	34	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	53	35	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 9-3
Advanced Maintenance
Scheduled Component Replacement
Forecast Scenario – NAAQS Growth

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	27	37	24	-	10	12	-	52	39	28	29	10	14	-	-	-	-
Gate Machinery	RM	10	15	15	RM	24	22	-	RM	10	10	RM	RM	15	RM	15	RM	RM
Hydraulic	RM	10	15	15	30	20	RM	-	RM	RM	RM	RM	RM	RM	RM	15	RM	RM
Culvert Valve	10	10	22	36	10	10	RM	-	-	54	-	RM	RM	-	-	-	-	-
Electrical	RM	10	15	15	RM	10	10	-	24	10	10	23	RM	14	15	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	15	35	16
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	10	14
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	50	-	-	-	-	RM	10	-	-	-	-	-	RM	52	34	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	RM	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	53	34	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 9-4
Advanced Maintenance
Scheduled Component Replacement
Forecast Scenario – Utility Based

Ohio River Mainstem Project																			
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	54	28	37	24	-	10	10	-	48	52	31	29	12	18	-	-	-	-
Gate Machinery	RM	15	27	20	RM	15	15	-	RM	15	RM	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	15	21	17	30	15	15	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	36	10	10	RM	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	10	17	15	RM	10	14	-	19	15	15	15	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	RM	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	51	RM	RM
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	51	-	-	-	-	RM	12	-	-	-	-	-	RM	57	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	45	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	RM	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	58	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

TABLE 9-5
Advanced Maintenance
Scheduled Component Replacement
Forecast Scenario – Utility Based High

Ohio River Mainstem Project																		
Chamber / Component	Smithland	J.T. Myers *	Newburgh	Cannelton	McAlpine	Markland	Meldahl	Greenup **	R.C. Byrd	Racine	Belleville	Willow Island	Hannibal	Pike Island	New Cumberland	Montgomery	Dashields	Emsworth
MAIN																		
Gates	51	27	37	24	-	10	10	-	45	52	30	29	12	16	-	-	-	-
Gate Machinery	RM	10	25	19	RM	15	14	-	RM	15	18	RM	RM	RM	RM	RM	RM	RM
Hydraulic	RM	10	19	16	28	15	14	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Culvert Valve	10	10	23	35	10	10	56	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	10	16	15	RM	10	10	-	14	15	15	15	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	33	RM	RM	RM	RM	RM	-	-	RM	RM	-	RM	RM	RM	35	RM	50
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM	RM
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	RM
AUX																		
Gates	50	-	-	-	-	RM	10	-	-	-	-	-	RM	56	37	-	-	-
Gate Machinery	RM	-	-	-	-	RM	-	-	-	-	-	RM	-	RM	RM	-	-	-
Hydraulic	RM	-	RM	RM	-	RM	RM	-	-	RM	RM	RM	-	RM	RM	RM	-	RM
Culvert Valve	10	-	RM	RM	-	41	-	-	-	RM	-	RM	RM	-	-	-	-	-
Electrical	RM	-	RM	RM	-	RM	58	-	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
Valve Machinery	RM	-	RM	-	-	RM	-	-	-	-	-	-	-	RM	-	-	-	-
Downstream Gates	-	-	-	-	-	-	-	-	-	-	-	-	-	56	38	-	-	-
Land Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-	-
Upper Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guard Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	RM	-
Lower Guide Wall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Myers is authorized and scheduled for an auxiliary chamber extension by 2010 (includes replacemane of gates and the electrical system).

** Greenup is authorized and scheduled for an auxiliary chamber extension by 2009 (which includes main chamber gate replacement in 2011).

9.3.2 Rehabilitation Maintenance

Sometimes the individual component replacement analysis indicates a potential cost savings if components can be bundled into a single closure. If a bundled component replacement exceeds $10.6 million the maintenance is considered a major rehabilitation.[2] Under major rehabilitation, where economically justified, all unreliable components are replaced. Unreliable components refers to any components determined economically justified for an up-front replacement

The opportunity for major rehabilitation was determined after the economics team identified components justified for individual replacement and the engineering team was able to bundle them into a single rehabilitation. Cost and closures for the rehabilitations were based on the cost to replace all the components and the time required to do it under one rehabilitation project. Since less mobilization and demobilization is required, rehabilitation costs and closures are usually improved over individual component replacements. If the bundled components did not exceed the rehabilitation threshold, then they were left as individual component replacements. ORNIM was run to determine rehabilitation justification and timing.

It should be noted that EDM was not evaluated for major rehabilitation maintenance because the physical condition of the lock walls at these project make a 2nd successful major rehabilitation unlikely. Note, that EDM was rehabilitated in the mid 1980s to early 1990s.

The rehabilitation maintenance alternative combines reactive maintenance with justified component replacements and chamber rehabilitations. **Table 9-6** summarizes recommended chamber rehabilitations for each traffic forecast scenario over the 2010-2070 timeframe. The gray shaded cells represent chambers not modeled because the individual component replacements would not exceed $10.6 million as required by major rehabilitation guidance. By the very nature of this analysis the results across forecasts are not always robust; there is variability between the traffic forecasts. Markland shows immediate rehabilitation justified in three of the five forecasts. The value of Table 9-6 is showing the relative sequencing of need for major rehabilitation studies with some projects in need of more accelerated study than others.

9.3.3 Auxiliary Lock Extensions – Lower Ohio

A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Lock extension plans were evaluated at Meldahl, Markland, Cannelton, and Newburgh. Based on traffic forecasts, these projects were considered most likely in need of additional auxiliary capacity.

[2] $10.6 million is the FY06 budgetary threshold for major rehabilitation

No auxiliary lock extensions were justified when ORNIM compared this alternative to the rehabilitation alternative. This suggests that a reliable main chamber negates the need for additional auxiliary capacity under the traffic forecast scenarios used in this analysis. Auxiliary lock extensions were dropped from further analysis.

TABLE 9-6
Recommended Chamber Rehabilitations

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Smithland					
Main	-	-	-	-	-
Auxiliary					
Myers					
Main	2014	2011	2013	2013	2013
Auxiliary					
Newburgh					
Main	2025	2016	2016	2016	2016
Auxiliary					
Cannelton					
Main	2017	2017	2016	2017	2017
Auxiliary					
McAlpine					
Main					
Auxiliary					
Markland					
Main	-	-	2010	2010	2010
Auxiliary	-	-	-	-	2052
Meldahl					
Main	2013	2010	2010	2010	2010
Auxiliary					
R. C. Byrd					
Main	-	2044	2045	2030	2033
Auxiliary					
Racine					
Main	2020	2019	2020	2019	2019
Auxiliary					
Belleville					
Main	-	2017	2017	2017	2028
Auxiliary					
Willow Island					
Main	2027	2027	2027	2027	2028
Auxiliary					
Hannibal					
Main	2012	2011	2011	2012	2011
Auxiliary					
Pike Island					
Main	2016	2015	2015	2016	2015
Auxiliary	-	-	-	-	-
New Cumberland					
Main					
Auxiliary	-	-	-	-	-

9.3.4 New 600' Locks at EDM

New 600' locks riverward of the existing auxiliary chambers at EDM were compared to reactive and advanced maintenance strategies. New 600' chambers at EDM were evaluated as stand-alone projects. This plan involves replacing the smaller (360' x 56') auxiliary locks at EDM with 600'x110' chambers. EDM would become twin 600' projects. The benefits of this plan are improved reliability and additional capacity.

ORNIM was run to determine new 600' lock justification and timing. The analysis shows new 600' locks justified at EDM relative to reactive and advanced maintenance strategies. The replacement 600' locks at EDM are in addition to reactive maintenance, justified component replacements, and major rehabilitations elsewhere on the mainstem. **Table 9-7** displays the optimal timing for 600' lock replacements at EDM by forecast scenario.

TABLE 9-7
Recommended New 600' Locks

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Emsworth					
Main	-	-	-	-	-
New 600' Lock	2010	2010	2010	2010	2010
Dashields					
Main	-	-	-	-	-
New 600' Lock	2011	2010	2010	2010	2010
Montgomery					
Main	-	-	-	-	-
New 600' Lock	2010	2010	2010	2010	2010

9.3.5 New 1200' Locks at EDM

New 1200' locks riverward of the existing auxiliary chambers at EDM were compared to reactive and advanced maintenance strategies, as well. New 1200' chambers at EDM were evaluated as stand-alone projects. This plan involves replacing the smaller (360' x 56') auxiliary locks at EDM with 1200'x110' chambers. The benefits of this plan are improved reliability and additional capacity.

ORNIM was run to determine new 1200' lock justification and timing. The analysis shows new 1200' locks justified at EDM relative to reactive and advanced maintenance strategies. The new replacement 1200' locks at EDM are in addition to reactive maintenance, justified component replacements and major rehabilitations elsewhere on the mainstem. **Table 9-8** displays the optimal timing for the 1200' lock replacements at EDM by forecast scenario.

TABLE 9-8
Recommended New 1200' Locks

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Emsworth					
Main	-	-	-	-	-
New 1200' Lock	2010	2010	2010	2010	2010
Dashields					
Main	-	-	-	-	-
New 1200' Lock	2012	2010	2010	2010	2010
Montgomery					
Main	-	-	-	-	-
New 1200' Lock	2014	2010	2010	2010	2010

9.3.6 Optimum Lock Size at EDM

ORNIM was run to optimize between 1200' and 600' chamber lock replacements at EDM. The optimum lock size at EDM alternative combines reactive maintenance with justified component replacements, major rehabilitations, and either a new 1200' or 600' lock at EDM. **Table 9-9** displays the optimal timing for the justified replacement locks at EDM by forecast scenario.

TABLE 9-9
Recommended Optimum New 1200' – 600' Locks

Project / Chamber	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Emsworth					
Main	-	-	-	-	-
New 600' Lock	2010	2010	2010	2010	2010
Dashields					
Main	-	-	-	-	-
New 600' Lock	2011	2010	2010	2010	2010
Montgomery					
Main	-	-	-	-	-
New 600' Lock	2010	2010	-	2010	2010
New 1200' Lock	-	-	2010	-	-

9.3.7 Congestion Lockage Fees

Although a detailed analysis of congestion fees has not been conducted for this study, a general analysis of traffic management alternatives was completed (see **Attachment 5 Traffic Management Analysis**) and some preliminary determinations have been made. A congestion lockage fee could be used to influence shipping decisions for shippers with

marginal transportation rate savings. A lockage fee could cause shippers to shift to either alternative transportation modes or markets, thereby reducing the amount of lock congestion for all remaining waterway shipments. Thus it serves to ration lock use to those movements with the highest transportation savings. The result would be an increase in total rate savings net of delay costs for shippers that continue to use the waterway. A congestion lockage fee could reduce arrivals (queues) and, therefore, delay costs at a congested lock during closure.

Congestion fees are generally considered to be an alternative to providing additional capacity at a public facility that is characterized by persistent delays and queues. In the case of the Ohio River mainstem locks and dams, congestion is associated with periodic closures of the main chambers rather than persistent congestion due to a system approaching capacity. The best way to manage these short-term and periodic episodes of congestion is with temporary nonstructural management measures such as industry self-help and n-up/n-down lockage policies. The implementation of long-term congestion fees based on short-term and periodic congestion would tend to distort the transportation practices of shippers in an uneconomical way. Furthermore, congestion fees do not address the structural problems of aging mainstem infrastructure. The one exception where congestion fees might prove to be of value is on the three Upper Ohio locks, where additional capacity for the auxiliary locks is economic.

9.3.8 Summary

The following investment alternatives: i) two proactive maintenance strategies and ii) new 600' or 1200' chambers at EDM are carried forward for economic analysis and formulation of the with-project condition (WPC). Congestion fees are not carried forward as part of the SIP WPC because they do not address the maintenance and structural investment needs of the mainstem.

9.4 ECONOMICS OF THE WITH-PROJECT ALTERNATIVES

9.4.1 Advanced Maintenance (Component Replacement)

Under advanced maintenance, normal O&M is performed, along with scheduled cyclical maintenance. Scheduled lock improvements for the mainstem include the authorized improvements at Greenup and J.T. Myers plus any justified individual component replacements. Unscheduled lock repair costs are estimated from reliability modeling. No major rehabilitation occurs. Scheduled dam maintenance, based on engineering judgment, is included in project costs.

9.4.1.1 System Costs

ORNIM was run at each project to estimate expected unscheduled repair/replace costs and component replacement costs under each of the five different traffic forecast scenarios. The unscheduled repair costs and scheduled component replacement costs are

added to other Federal maintenance costs to develop total system costs. **Figure 9-2** shows forecast advanced maintenance funding needs. Overall, this analysis shows an average annual expenditure of around $100.6 million is required to sustain navigation on the Ohio River from 2010-2070 with an advanced maintenance strategy.

FIGURE 9-2

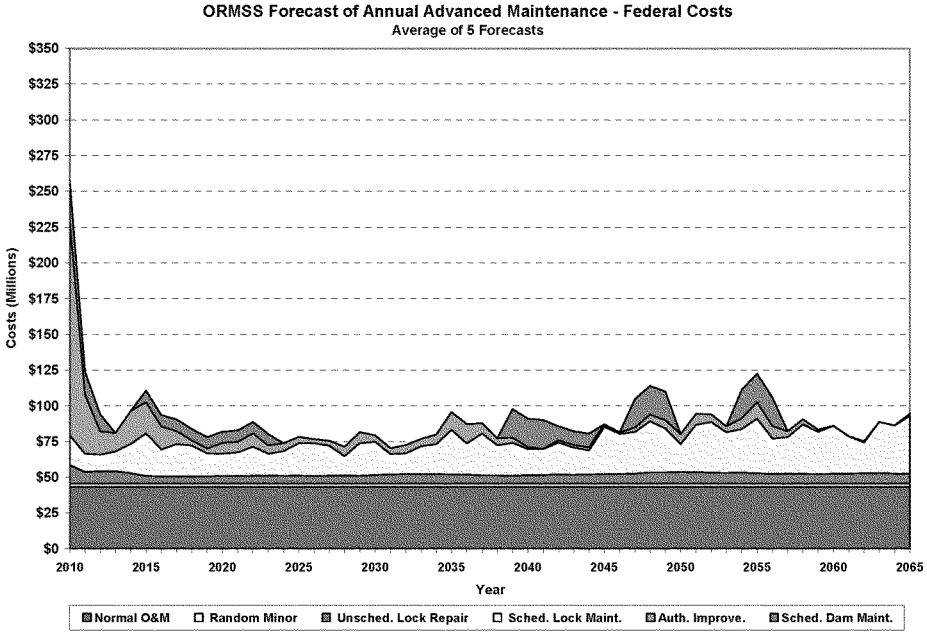
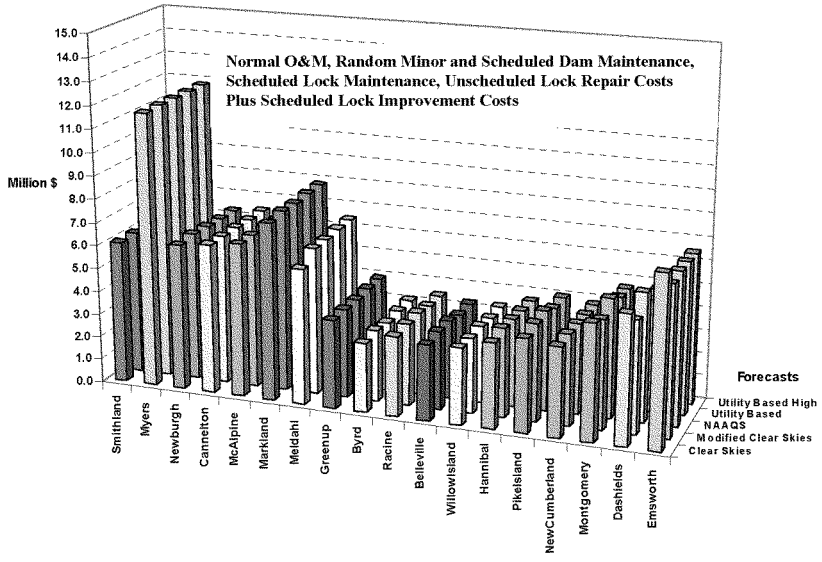


Figure 9-3 displays average annual Federal costs for the advanced maintenance alternative by project and by traffic forecast. The bar graph combines normal O&M, random minor, scheduled dam costs, scheduled lock maintenance costs, unscheduled lock repair costs, and lock improvement costs. The scheduled lock improvements are the authorized J.T. Myers and Greenup improvements and the economically justified component replacements displayed in Tables 9-1 through 9.5. Unscheduled lock repair costs and scheduled lock maintenance costs are lower because of proactive component replacement efficiencies. High maintenance needs are seen on the upper and lower Ohio projects. J.T. Myers shows authorized improvement costs.

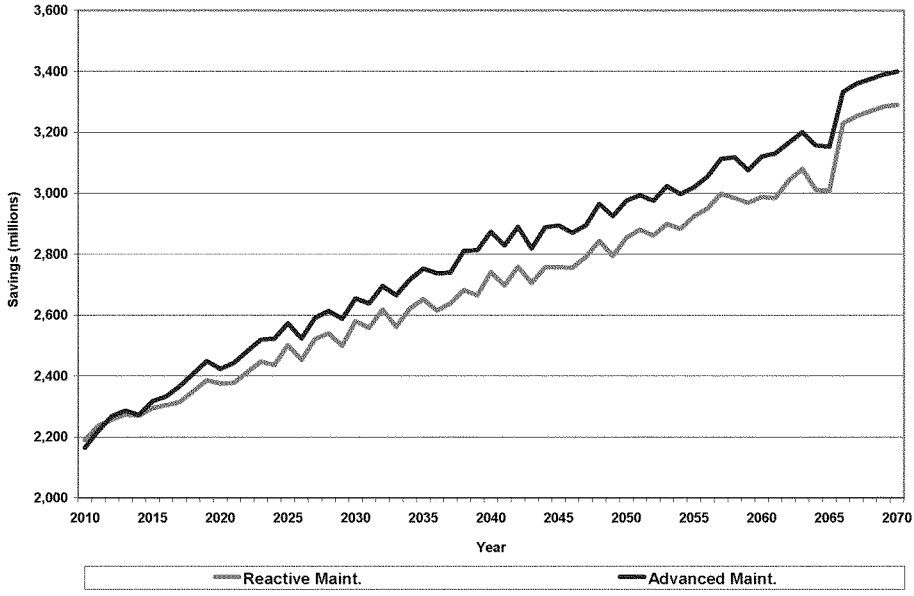
FIGURE 9-3
Advanced Maintenance
Average Annual Project Costs
(2010-2070, 5 1/8%, FY03 $)



9.4.1.2 System Benefits

System benefits are the equilibrium transportation rate savings net of any transportation losses caused by congestion or delay due to scheduled improvement and unscheduled repair closures. **Figure 9-4** displays system transportation benefits averaged over all 5 traffic forecast scenarios for the reactive and advanced maintenance strategies. The gap represents incremental system benefits attributable to the more aggressive advanced maintenance strategy.

FIGURE 9-4
ORMSS Forecast of Annual Advanced Maintenance Transportation Benefits
Average of 5 Forecasts



9.4.1.3 System Statistics

Individual component replacement optimization was done at the project level in a system context. The simultaneous effect of multiple piecemeal component replacements at each project and between each project is captured by locking the recommended replacements for all projects and re-equilibrating the transportation system. Given the results of individual up front component replacement analysis, ORNIM was run to calculate the expected system component replacement costs under each of the five traffic forecast scenarios. **Table 9-10** summarizes average annual system benefits and costs from an advanced maintenance strategy at each mainstem project over the five traffic forecast scenarios.

Advanced maintenance buys down risk with higher scheduled improvement costs that are 50 percent cost shared with the Trust Fund. Scheduled improvement costs for this alternative include Greenup and Myers and justified up-front component replacements shown in **Tables 9-1** to **9-5**. Scheduled lock maintenance and unscheduled lock repair costs are 100 percent Federal and decrease. Average annual benefits range from $2.37 to $2.58 billion. Average annual costs range from $100.3 to $101.7 million.

Table 9-11 displays incremental benefits and costs of advanced maintenance compared to reactive maintenance plans. Incremental costs are slightly positive because the higher improvement costs exceed slightly the lower scheduled lock maintenance and unscheduled lock repair costs, for all forecast traffic scenarios. In the long run, it is more

economic to pursue an up-front component replacement strategy rather than a reactive maintenance strategy. The table shows incremental net benefits of a planned component replacement ranging from $94.8 to $172.4 million annually.

TABLE 9-10
Advanced Maintenance*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Advanced Maintenance Benefits					
Equilibrium Waterway Savings	$2,383.4	$2,543.2	$2,563.0	$2,590.8	$2,645.6
Reduced Savings from Unscheduled Repair	($17.6)	($74.4)	($37.0)	($56.3)	($61.2)
Total System Benefits	**$2,365.8**	**$2,468.8**	**$2,526.0**	**$2,534.5**	**$2,584.4**
Advanced Maintenance Costs					
Scheduled Lock Maintenance	$ 20.7	$ 20.9	$ 20.4	$ 21.1	$ 20.9
Scheduled Dam Maintenance	$ 6.9	$ 6.9	$ 6.9	$ 6.9	$ 6.9
Scheduled Lock Improvements*	$ 19.7	$ 15.0	$ 20.2	$ 15.2	$ 15.6
Unscheduled Lock Repair	$ 4.3	$ 8.4	$ 5.0	$ 7.6	$ 7.7
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$101.8**	**$100.4**	**$101.7**	**$100.0**	**$100.3**
Net Benefits	**$2,265.0**	**$2,368.4**	**$2,424.2**	**$2,434.5**	**$2,484.1**
BCR	**23.5**	**24.6**	**24.8**	**25.3**	**25.8**

** Scheduled Lock Improvements are 50% cost shared with the Trust Fund for the authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, plus any justified component replacements.*

TABLE 9-11
Advanced Maintenance
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$113.0	$95.1	$174.1	$105.8	$124.3
Incremental Costs over Reactive Maintenance	$1.7	$0.3	$1.7	$0.3	$0.2
Net Incremental Benefit	**$111.3**	**$94.8**	**$172.4**	**$105.5**	**$124.1**

9.4.2 Rehabilitation Maintenance

Under rehabilitation maintenance, normal O&M is performed, along with scheduled cyclical maintenance. Scheduled lock improvements for the mainstem include the authorized improvements at Greenup and J.T. Myers, justified individual component replacements, plus any justified rehabilitations. Unscheduled lock repair costs are computed from reliability modeling. Scheduled dam maintenance, based on engineering judgment, is included in project costs.

9.4.2.1 System Costs

ORNIM was run at each project to estimate expected unscheduled repair/replace costs, component replacement costs and major rehabilitations under each of the five different traffic forecast scenarios. The unscheduled repair costs, the scheduled component replacement costs, and the major rehabilitation costs are added to other Federal maintenance costs to develop total system costs. **Figure 9-5** shows forecast rehabilitation maintenance funding needs. Overall, this analysis shows an average annual expenditure of around $98.1 million is required to sustain navigation on the Ohio River from 2010-2070 with a rehabilitation maintenance strategy. In the long run, a rehabilitation maintenance strategy is lower cost than either reactive or advanced maintenance.

FIGURE 9-5

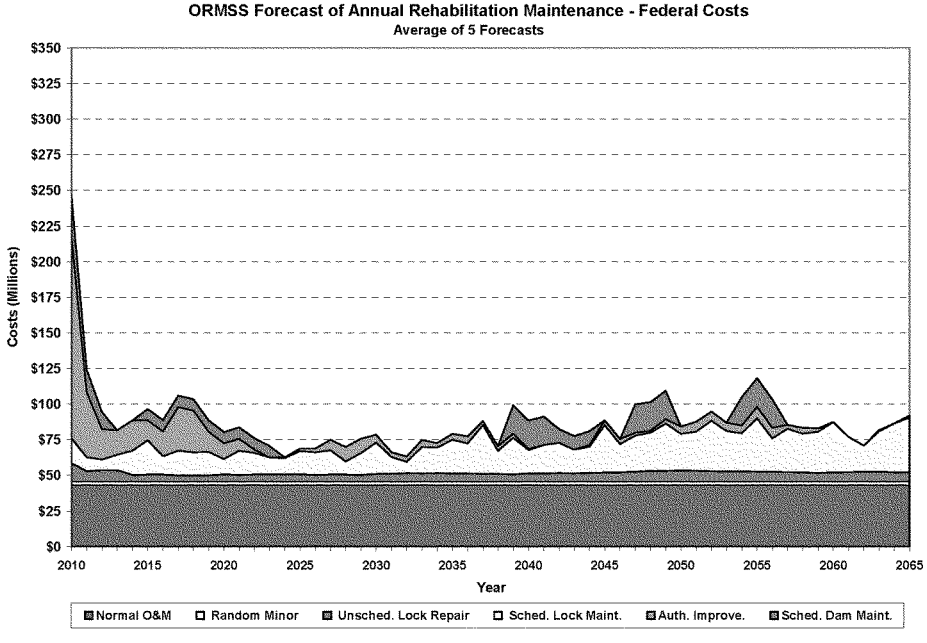
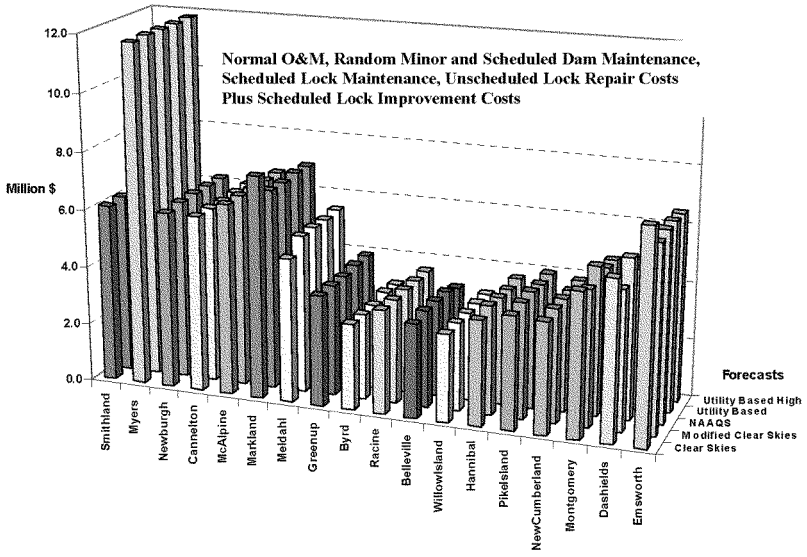


Figure 9-6 displays average annual Federal costs for the rehabilitation maintenance alternative by project and by traffic forecast. The bar graph combines normal O&M, random minor, scheduled dam costs, scheduled lock maintenance costs, unscheduled lock repair costs and lock improvement costs. The scheduled lock improvements are the authorized Myers and Greenup improvements, the economically justified component replacements and the recommended rehabilitations shown in **Table 9-6**. The unscheduled lock repair costs and scheduled lock maintenance costs are lower because of rehabilitation efficiencies.

Costs for early rehabilitation needs at Markland, Hannibal, Meldahl, Myers, Pike Island, Willow Island, Newburgh and Cannelton as well as maintenance costs at Emsworth, Dashields, and Montgomery are included in **Figure 9-6**. Also, costs at Myers include the authorized auxiliary chamber extension.

FIGURE 9-6
Rehabilitation Maintenance
Average Annual Project Costs
(2010-2070, 5 1/8%, FY03 $)

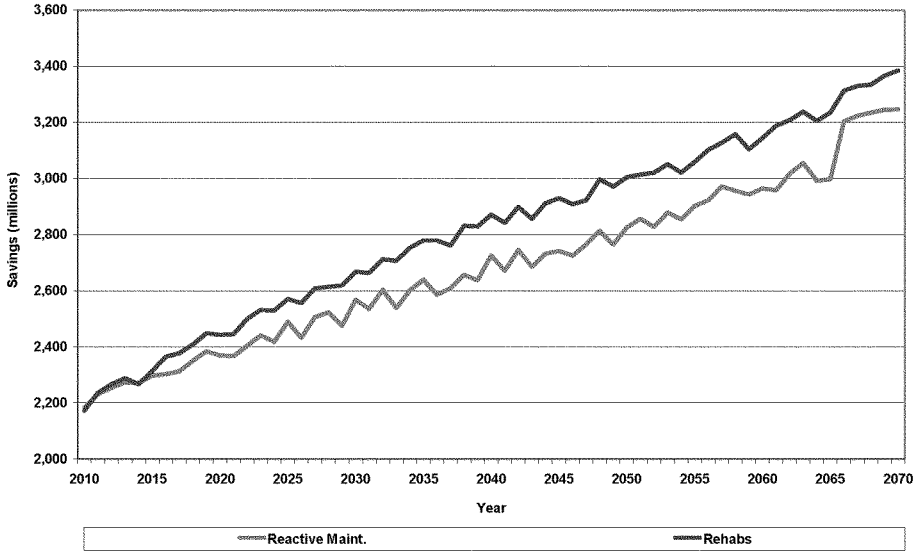


9.4.2.2 System Benefits

System benefits are the equilibrium transportation rate savings net of any transportation losses caused by congestion or delay due to scheduled improvement and unscheduled repair closures. **Figure 9-7** displays system transportation benefits averaged over all 5 traffic forecast scenarios for the reactive and rehabilitation maintenance

strategies. The gap represents incremental system benefits attributable to the more aggressive component replacement and rehabilitation maintenance strategy.

FIGURE 9-7
ORMSS Forecast of Annual Rehabilitation Maintenance Transportation Benefits
Average of 5 Forecasts



9.4.2.3 System Statistics

Bundled component replacement optimization was done at the project level in a system context. The simultaneous effect of bundling component replacements at each project and between each project is captured by locking the recommended replacements for all projects and re-equilibrating the transportation system. Given the results of bundled component replacement analysis, ORNIM was run to calculate the expected system component replacement costs under each of the five traffic forecast scenarios. **Table 9-12** summarizes average annual system benefits and costs from a rehabilitation maintenance strategy at each mainstem project over the five traffic forecast scenarios. Scheduled improvement costs for this alternative include Greenup and Myers, justified up-front component replacements and justified major rehabilitation work shown in **Table 9-6**. Unscheduled repair costs decrease further with the rehabilitation maintenance strategy. Average annual benefits range from $2.37 to $2.60 billion. Average annual costs range from $97.4 to $99.0 million.

Table 9-13 displays incremental benefits and costs of rehabilitation maintenance compared to reactive maintenance plans. Incremental costs are negative because rehabilitation maintenance is a more efficient maintenance strategy than reactive maintenance. In the long run, it is more economic to perform bundled component

replacements compared to reactive maintenance. The table also shows the incremental net benefits of planned rehabilitations. Incremental net benefits range from $115.7 to $183.2 million.

TABLE 9-12
Rehabilitation Maintenance*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Rehabilitation Maintenance Benefits					
Equilibrium Waterway Savings	$2,386.2	$2,565.1	$2,570.7	$2,602.1	$2,659.1
Reduced Savings from Unscheduled Repair	($17.6)	($62.7)	($36.9)	($56.1)	($61.5)
Total System Benefits	**$2,368.6**	**$2,502.4**	**$2,533.8**	**$2,546.1**	**$2,597.7**
Rehabilitation Maintenance Costs					
Scheduled Lock Maintenance	$18.3	$17.4	$17.0	$17.6	$17.5
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements*	$20.4	$16.7	$20.9	$16.7	$16.6
Unscheduled Lock Repair	$4.2	$7.4	$4.8	$7.3	$7.3
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.4	$2.4	$2.4	$2.4	$2.4
Total System Costs	**$99.0**	**$97.6**	**$98.8**	**$97.7**	**$97.4**
Net Benefits	**$2,269.5**	**$2,404.8**	**$2,435.0**	**$2,448.4**	**$2,500.2**
BCR	**23.9**	**25.6**	**25.7**	**26.1**	**26.7**

** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements plus justified rehabilitations.*

TABLE 9-13
Rehabilitation Maintenance
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$115.7	$128.7	$181.9	$117.4	$137.5
Incremental Costs over Reactive Maintenance	($0.0)	($2.5)	($1.3)	($2.1)	($2.6)
Net Incremental Benefit	**$115.7**	**$131.2**	**$183.2**	**$119.5**	**$140.2**

9.4.3 New 600' Locks at EDM

Under new 600' locks at EDM, normal O&M is performed, along with scheduled cyclical maintenance for inspection. Scheduled lock improvements include the authorized improvements at Greenup and J.T. Myers, justified component replacements, justified rehabilitations and justified new 600' locks at EDM. Unscheduled lock repair costs are estimated from reliability modeling. Scheduled dam maintenance, based on engineering judgment, is included in project costs.

9.4.3.1 System Costs

ORNIM was run at all projects to estimate expected unscheduled repair/replace costs, component replacement costs, major rehabilitation costs and new 600' locks at EDM under each of the five different traffic forecast scenarios. The unscheduled repair costs, scheduled component replacement costs, major rehabilitation costs, and new 600' lock construction costs are added to other Federal maintenance costs to develop total system costs. **Figure 9-8** shows forecast Federal funding needs for a new 600' lock at EDM alternative. There is a spike in authorized improvement costs relative to the maintenance alternative cost graphics. Overall, this analysis shows that an average annual expenditure of $118.5 million is required to sustain navigation on the Ohio River from 2010-2070 with the new 600' locks at EDM alternative. New construction at EDM lowers future unscheduled lock repair and scheduled maintenance relative to reactive maintenance.

FIGURE 9-8

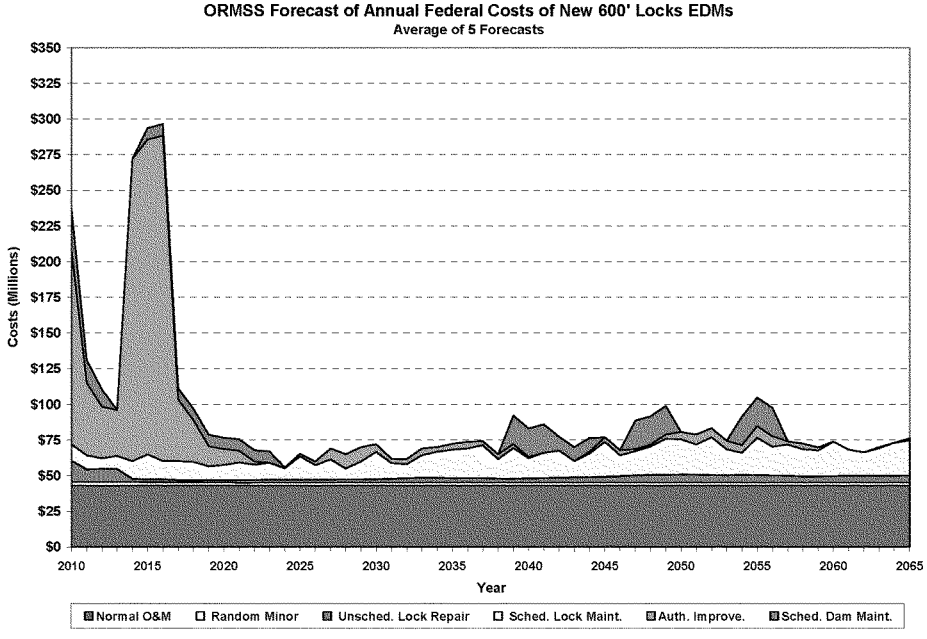
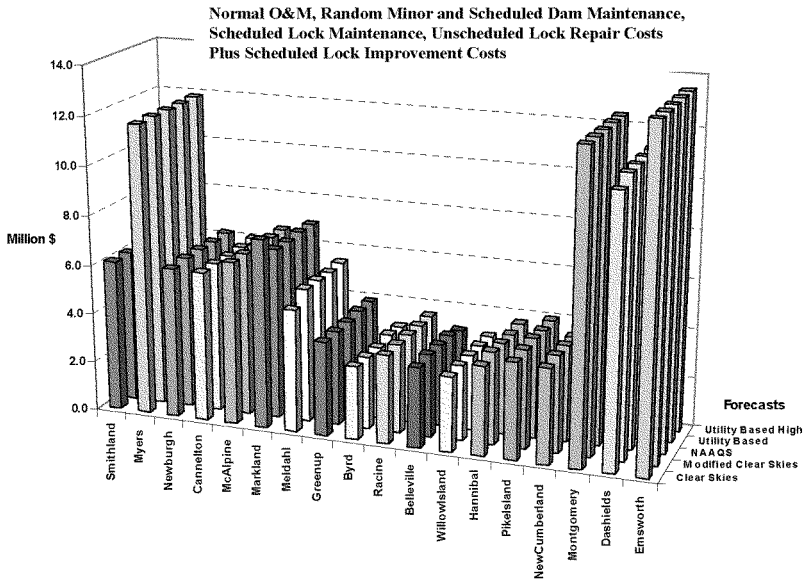


Figure 9-9 displays average annual Federal costs for the new 600' locks at EDM alternative by project and by traffic forecast. The bar graph combines normal O&M, random minor closure costs, scheduled dam costs, scheduled lock maintenance costs, unscheduled lock repair costs, and lock improvement costs. The scheduled lock improvements are the authorized J.T. Myers and Greenup improvements, economically justified component replacements and recommended rehabilitations plus the justified new 600' locks at EDM shown in **Table 9-7**. The unscheduled lock repair costs and the scheduled lock maintenance costs are lower because of the new construction.

Figure 9-9 shows new construction costs at EDM dominating annual system investment costs, with the authorized Myers auxiliary chamber extension standing out as well and the rehabilitation needs at Markland, Hannibal, Meldahl, Myers, Pike Island, Willow Island, Newburgh, and Cannelton.

FIGURE 9-9
600' Locks EDM
Average Annual Project Costs
(2010-2070, 5 1/8%, FY03 $)

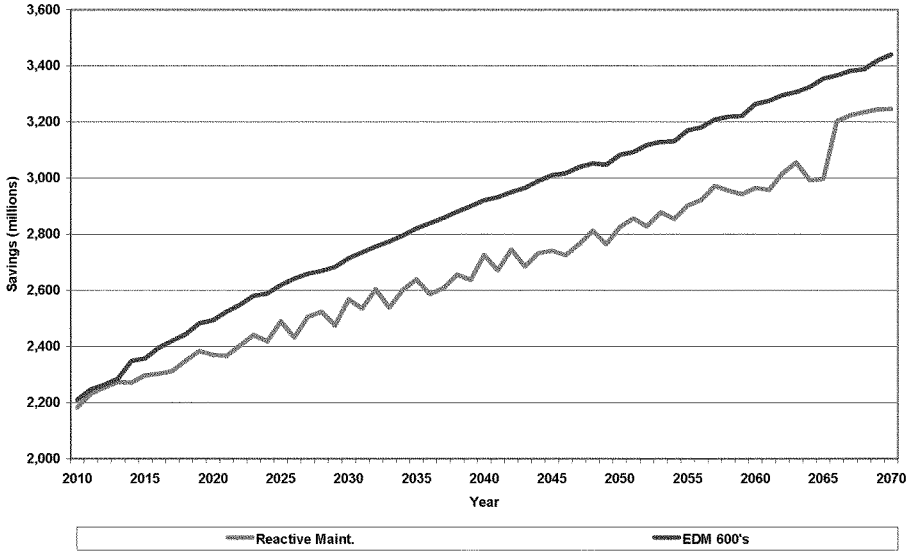


9.4.3.2 System Benefits

System benefits are the equilibrium transportation rate savings net of any transportation losses caused by congestion or delay due to scheduled improvement and unscheduled repair closures. **Figure 9-10** displays system transportation benefits averaged over all 5 traffic forecast scenarios for the reactive maintenance strategy and for the new 600' locks at EDM alternative. The gap represents incremental system benefits to the

more aggressive component replacement and rehabilitation maintenance strategies and the new locks at EDM.

FIGURE 9-10
ORMSS Forecast of New 600' Locks at EDM Transportation Benefits
Average of 5 Forecasts



9.4.3.3 System Statistics

Table 9-14 summarizes average annual system benefits and costs of constructing new 600' locks at EDM on top of rehabilitations, component replacements, and reactive maintenance elsewhere on the mainstem. Scheduled improvement costs for this alternative include Greenup and Myers, justified up-front component replacements, major rehabilitation work, and new 600' locks at EDM shown in **Table 9-7**. Average annual benefits range from $2.40 to $2.69 billion. Average annual costs range from $118.0 to $118.7 million.

Table 9-15 displays incremental benefits and costs of the 600' locks at EDM in conjunction with rehabilitations, component replacements, and reactive maintenance compared to the base-level WOPC (reactive maintenance only). Incremental costs are larger because of the new construction investment. The incremental net benefit of new 600' locks at EDM ranges from $128.8 to $235.0 million.

TABLE 9-14
New 600' Locks EDM*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
New 600' Locks EDM Benefits					
Equilibrium Waterway Savings	$2,413.5	$2,631.5	$2,624.5	$2,656.5	$2,717.0
Reduced Savings from Unscheduled Repair	($12.9)	($20.7)	($19.1)	($20.8)	($23.6)
Total System Benefits	**$2,400.6**	**$2,610.7**	**$2,605.4**	**$2,635.7**	**$2,693.4**
New 600' Locks EDM Costs					
Scheduled Lock Maintenance	$15.2	$14.0	$13.9	$14.0	$14.0
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements*	$43.0	$44.6	$44.7	$44.7	$44.5
Unscheduled Lock Repair	$4.0	$4.3	$4.2	$4.2	$4.2
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.2	$2.2	$2.2	$2.2	$2.2
Total System Costs	**$118.0**	**$118.7**	**$118.6**	**$118.7**	**$118.5**
Net Benefits	**$2,282.6**	**$2,492.0**	**$2,486.8**	**$2,517.0**	**$2,574.9**
BCR	**20.3**	**22.0**	**22.0**	**22.2**	**22.7**

**Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include aAuthorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements, justified rehabilitations plus new 600' locks at EDM.*

TABLE 9-15
New 600' Locks EDM
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$147.8	$237.0	$253.6	$207.0	$233.3
Incremental Costs over Reactive Maintenance	$19.0	$18.6	$18.6	$18.9	$18.4
Net Incremental Benefit	**$128.8**	**$218.4**	**$235.0**	**$188.1**	**$214.9**

9.4.4 New 1200' Locks at EDM

Under new 1200' locks at EDM, normal O&M is performed, along with scheduled cyclical maintenance for inspection. Scheduled lock improvements include the authorized improvements at Greenup and Myers, justified component replacements, justified rehabilitations, justified lock extensions, plus any justified new 1200' locks at EDM.

Unscheduled lock repair costs are estimated from reliability modeling. Scheduled dam maintenance, based on engineering judgment, is included in project costs.

9.4.4.1 System Costs

ORNIM was run at all projects to estimate expected unscheduled repair/replace costs, component replacement costs, major rehabilitation costs, and the cost of new 1200' locks at EDM under each of the five different traffic forecast scenarios. The unscheduled repair costs, scheduled component replacement costs, major rehabilitation costs, and new 1200' lock construction costs are added to other Federal maintenance costs to develop total system costs. **Figure 9-11** shows forecast for Federal funding needs under the new 1200' locks at EDM alternative. Notice the spike in authorized improvement costs relative to the maintenance alternative cost graphics. Overall, this analysis shows an average annual expenditure of $124.5 million is required to sustain navigation on the Ohio River from 2010-2070 with the new 1200' locks at EDM alternative. New construction at EDM lowers future unscheduled lock repair and scheduled maintenance relative to reactive maintenance.

FIGURE 9-11

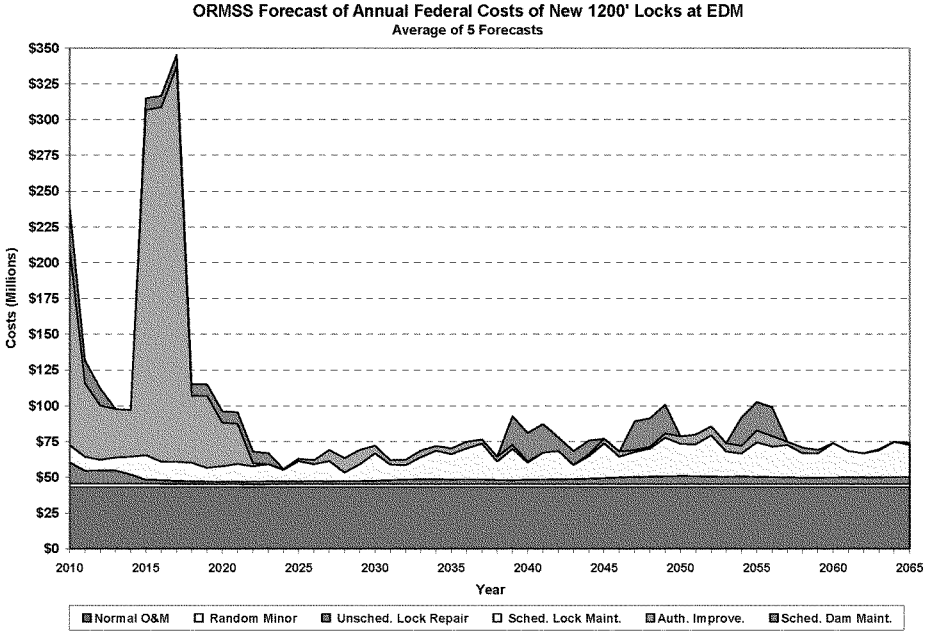
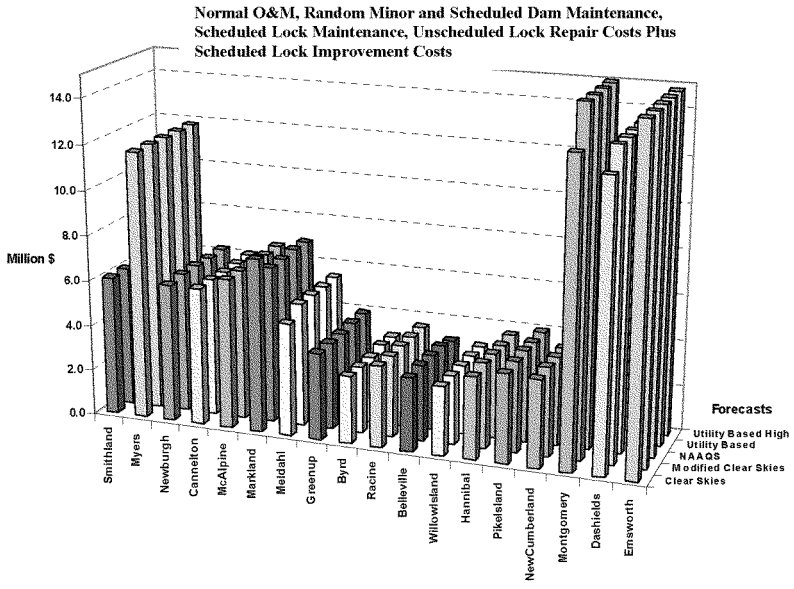


Figure 9-12 displays average annual Federal costs for the new 1200' locks at EDM alternative by project and by traffic forecast. The bar graph combines normal O&M costs, random minor closure costs, scheduled dam costs, scheduled lock maintenance costs, unscheduled lock repair costs, and lock improvement costs. The scheduled lock

improvements are the authorized Myers and Greenup improvements, the economically justified component replacements, recommended rehabilitations, plus the justified new 1200' locks at EDM shown in **Table 9-8**. The unscheduled lock repair costs and the scheduled lock maintenance costs are lower because of the new construction.

Figure 9-12 shows new construction costs at EDM dominating system investment costs, with the authorized Myers auxiliary chamber extension standing out as well and the rehabilitation needs at Markland, Hannibal, Meldahl, Myers, Pike Island, Willow Island, Newburgh, and Cannelton.

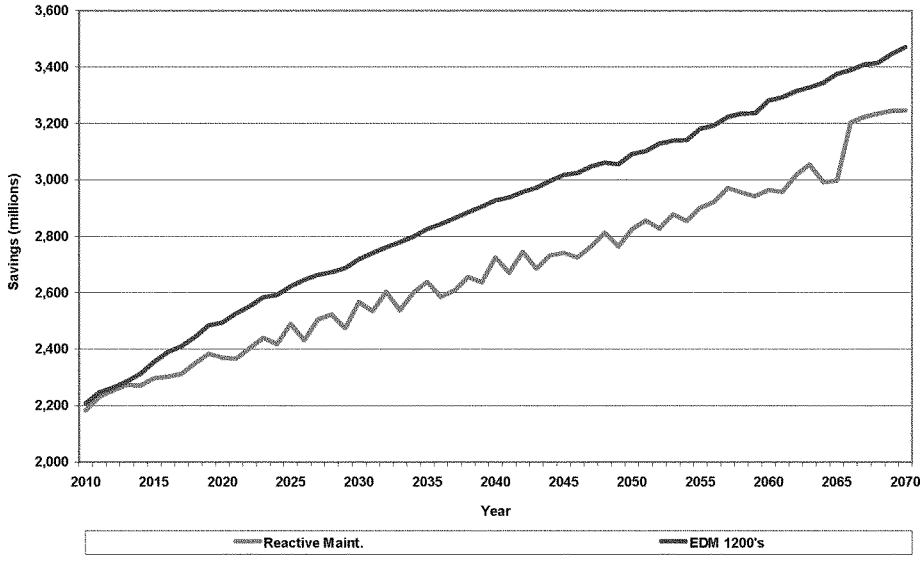
FIGURE 9-12
1200' Locks EDM
Average Annual Project Costs
(2010-2070, 5 1/8%, FY03 $)



9.4.4.2 System Benefits

System benefits are the equilibrium transportation rate savings net of any transportation losses caused by congestion or delay due to scheduled improvement and unscheduled repair closures. **Figure 9-13** displays system transportation benefits averaged over all 5 traffic forecast scenarios for the new 1200' locks at EDM alternative and reactive maintenance. The gap represents incremental system benefits attributable to the more aggressive maintenance and new construction associated with the new 1200' locks at EDM alternative.

FIGURE 9-13
ORMSS Forecast of New 1200' Locks at EDM Transportation Benefits
Average of 5 Forecasts



9.4.4.3 System Statistics

Table 9-16 summarizes average annual system benefits and costs of constructing new 1200' locks at EDM on top of rehabilitations, component replacements and reactive maintenance elsewhere on the mainstem. Scheduled improvement costs for this alternative include Greenup and Myers, justified up-front component replacements, major rehabilitation work, and new 1200' locks at EDM shown in **Table 9-8**. Average annual benefits range from $2.40 to $2.69 billion. Average annual costs range from $121.9 to $125.2 million.

Table 9-17 displays incremental benefits and costs of the 1200' locks at EDM in conjunction with rehabilitations, component replacements and reactive maintenance compared to the base-level WOPC (reactive maintenance only). Incremental costs are positive because of the investment required. The table also shows the incremental net benefits of the new 1200' locks at EDM. Incremental net benefits range from $120.5 to $234.9 million.

TABLE 9-16
New 1200' Locks EDM*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
New 1200' Locks EDM Benefits					
Equilibrium Waterway Savings	$2,411.8	$2,633.7	$2,632.4	$2,656.6	$2,717.7
Reduced Savings from Unscheduled Repair	($15.6)	($22.6)	($20.5)	($22.7)	($25.6)
Total System Benefits	**$2,396.2**	**$2,611.1**	**$2,611.8**	**$2,633.9**	**$2,692.1**
New 1200' Locks EDM Costs					
Scheduled Lock Maintenance	$15.2	$13.9	$13.8	$13.9	$14.0
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements*	$46.4	$50.9	$51.0	$50.9	$50.8
Unscheduled Lock Repair	$4.5	$4.5	$4.4	$4.4	$4.4
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.2	$2.2	$2.2	$2.2	$2.2
Total System Costs	**$121.9**	**$125.2**	**$125.1**	**$125.1**	**$125.0**
Net Benefits	**$2,274.3**	**$2,485.9**	**$2,486.7**	**$2,508.8**	**$2,567.2**
BCR	**19.7**	**20.9**	**20.9**	**21.1**	**21.5**

** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include aAuthorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements, justified rehabilitations plus new 1200' locks at EDM.*

TABLE 9-17
New 1200' Locks EDM
Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$143.4	$237.4	$260.0	$205.2	$232.0
Incremental Costs over Reactive Maintenance	$22.9	$25.1	$25.1	$25.4	$24.9
Net Incremental Benefit	**$120.5**	**$212.3**	**$234.9**	**$179.8**	**$207.1**

9.4.5 Optimum Lock Size at EDM

ORNIM was run to optimize between 600' and 1200' chambers at EDM. With new 1200' or 600' locks at EDM, normal O&M is performed, along with scheduled cyclical maintenance for inspection. Scheduled lock improvements include the authorized improvements at Greenup and Myers, justified component replacements and rehabilitations, plus justified new 1200' or 600' locks at EDM. Unscheduled lock repair costs are estimated from reliability modeling. Scheduled dam maintenance, based on engineering judgment, is included in project costs.

Table 9-18 summarizes average annual system benefits and costs of the optimum lock size at EDM. Scheduled improvement costs for this alternative include Greenup and Myers, justified up-front component replacements, major rehabilitation work, and new locks at EDM as shown in **Table 9-9**. Average annual benefits range from $2.407 to $2.69 billion. Average annual costs range from $118.0 to $121.5 million.

TABLE 9-18
Optimum Lock Size at EDM*
Average Annual Costs and Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Optimum Lock Size at EDM Benefits					
Equilibrium Waterway Savings	$2,413.5	$2,631.5	$2,631.0	$2,656.5	$2,717.0
Reduced Savings from Unscheduled Repair	($12.9)	($20.7)	($19.4)	($20.8)	($23.6)
Total System Benefits	**$2,400.6**	**$2,610.7**	**$2,611.7**	**$2,635.7**	**$2,693.4**
Optimum Lock Size at EDM Costs					
Scheduled Lock Maintenance	$15.2	$14.0	$13.9	$14.0	$14.0
Scheduled Dam Maintenance	$6.9	$6.9	$6.9	$6.9	$6.9
Scheduled Lock Improvements*	$43.0	$44.6	$47.6	$44.7	$44.5
Unscheduled Lock Repair	$4.0	$4.3	$4.2	$4.2	$4.2
Normal O&M	$46.7	$46.7	$46.7	$46.7	$46.7
Random Minor	$2.2	$2.2	$2.2	$2.2	$2.2
Total System Costs	**$118.0**	**$118.7**	**$121.5**	**$118.7**	**$118.5**
Net Benefits	**$2,282.6**	**$2,492.0**	**$2,490.1**	**$2,517.0**	**$2,574.9**
BCR	**20.3**	**22.0**	**21.5**	**22.2**	**22.7**

** Scheduled Lock Improvements are 50% cost shared with the Trust Fund and include authorized 600' extension of the auxiliary chamber at Myers in 2010 and rehabilitation of the Greenup main chamber in 2010-11, justified component replacements, justified rehabilitations plus optimum of 1200'- 600' locks at EDM.*

Table 9-19 displays incremental benefits and costs of the optimally-sized locks at EDM in conjunction with rehabilitations, component replacements, and reactive maintenance compared to the base-level WOPC (reactive maintenance only). Incremental costs are positive because of the investment required. The table also shows the incremental net benefits of the new 1200' or 600' locks at EDM. Incremental net benefits range from $128.8 to $238.3 million.

TABLE 9-19
Optimum Lock Size at EDM
Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over Reactive Maintenance	$147.8	$237.0	$259.8	$207.0	$233.3
Incremental Costs over Reactive Maintenance	$19.0	$18.6	$21.5	$18.9	$18.4
Net Incremental Benefit	**$128.8**	**$218.4**	**$238.3**	**$188.1**	**$214.9**

9.5 THE WITH-PROJECT CONDITION

The optimum lock size at EDM is a 600' chamber for four of five traffic forecast scenarios. Only in the NAQQS traffic forecast scenario is a 1200' new chamber recommended at Montgomery. Included in the optimized EDM alternative are chamber rehabilitations according to **Table 9-6**. **Table 9-20** shows the average annual benefits net of system costs for the WOPC and each investment alternative. The optimized EDM alternative maximizes net benefits across all traffic forecast scenarios and is thus selected as the with-project condition.

TABLE 9-20
Average Annual Net Benefits
(2010-2070, 5 1/8%, Million FY03 $)

Alternative	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
WOPC	$ 2,154	$ 2,274	$ 2,252	$ 2,329	$ 2,360
Advanced Maintenance	$ 2,265	$ 2,368	$ 2,424	$ 2,435	$ 2,484
Rehabilitaion Maintenance	$ 2,270	$ 2,405	$ 2,435	$ 2,448	$ 2,500
New 600' Locks EDM	$ 2,283	$ 2,492	$ 2,487	$ 2,517	$ 2,575
New 1200' Locks EDM	$ 2,274	$ 2,486	$ 2,487	$ 2,509	$ 2,567
Optimized EDM	**$ 2,283**	**$ 2,492**	**$ 2,490**	**$ 2,517**	**$ 2,575**

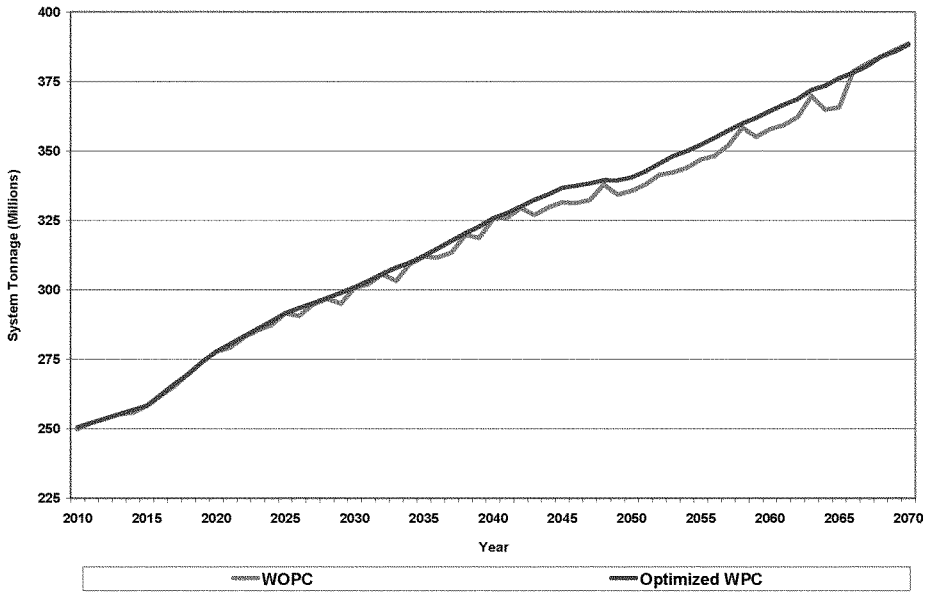
9.5.1 With-Project Condition System Statistics

The with-project condition (WPC) contains a combination of structural improvements and operational and maintenance strategies to optimize Ohio River mainstem navigation for the next 60 years. This sub-section compares WPC system statistics to WOPC system statistics.

9.5.1.1 Equilibrium System Tonnage

Figure 9-14 displays equilibrium system traffic accommodated in the WOPC and WPC. The gap represents incremental diverted traffic between the WOPC and WPC. Over the period of analysis, an average of 2.9 million tons of additional commercial traffic is diverted each year in the WOPC. This additional diverted traffic would challenge overland carrying capacity and increase congestion, traffic accidents, and pollutant emissions.

FIGURE 9-14
Equilibrium System Traffic
(Million Tons)

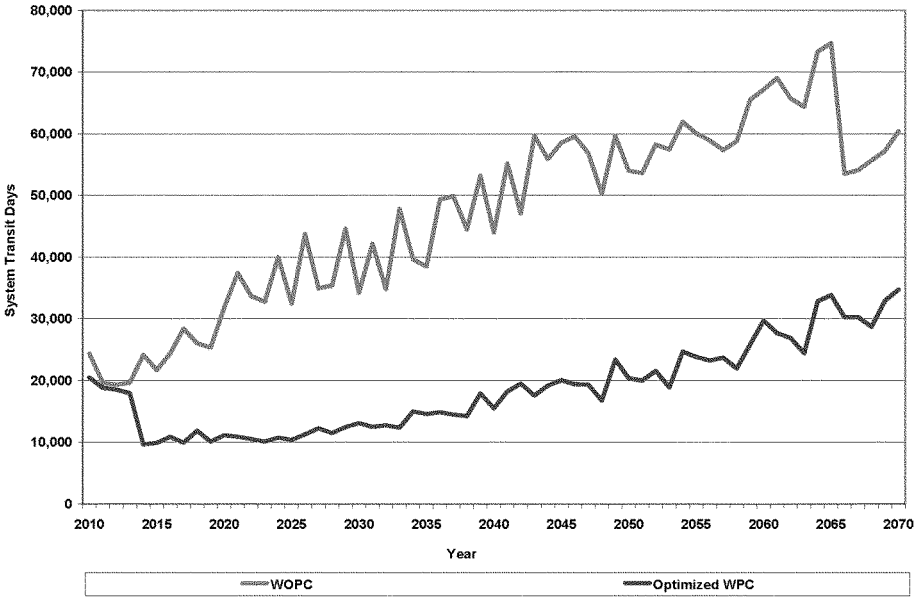


9.5.1.2 System Transit Days

Figure 9-15 compares system equilibrium traffic transit time (averaged over all five traffic scenarios) between the WOPC and WPC alternatives. With-project benefits are derived from a more efficient transportation system because of improved reliability and increased capacity. Capacity increases with fewer closures and the newer, larger chambers. System downtime decreases. The lower-river rehabs and upper-river new lock chambers reduce total system transit days relative to the WOPC.

The drop in transit days from 2013-2014 in the WPC is due to the new locks at EDM and the main chamber rehabs at Markland, Hannibal, Meldahl, Myers and Pike Island all coming on-line. The volatility in transit days seen in the WOPC curve results from the unreliability and more frequent scheduled closures found with the reactive maintenance strategy.

FIGURE 9-15
Transit Days to Accommodate Equilibrium Traffic
(WOPC vs. WPC)

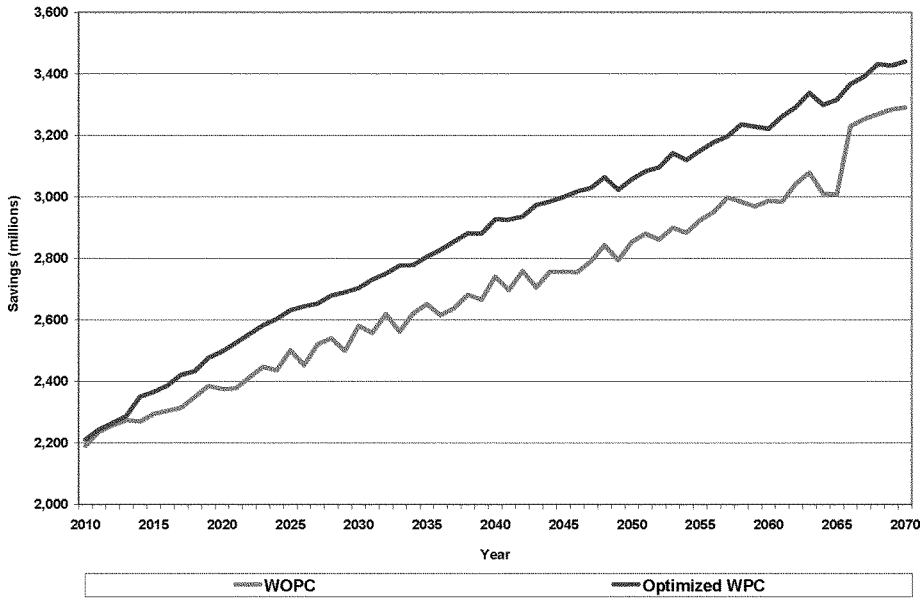


9.5.1.3 System Savings

Figure 9-16 displays system transportation savings averaged over all 5 traffic forecast scenarios for the optimized WPC and WOPC. Equilibrium transportation savings

represent system benefits in accordance with ER 1105-2-100. The gap represents incremental system benefits attributable to the more aggressive maintenance and new construction associated with the optimized WPC.

FIGURE 9-16
Equilibrium System Savings
(Million Dollars)



9.5.1.4 WPC Annual Incremental Benefits and Costs

Table 9-21 displays the average annual incremental benefits and costs, net benefits, and BCRs for the WPC under all 5 traffic forecast scenarios. Annual incremental benefits range from $147.8 to $259.9 million and annual incremental costs range from $18.4 to $21.5 million.

TABLE 9-21
WPC Average Annual Incremental Benefits and Costs
(2010-2070, 5 1/8%, Million FY03 $)

Ohio Mainstem System	Forecast Scenario				
	Clear Skies	Modified Clear Skies	NAAQS Growth	Utility Based	Utility Based High
Incremental Benefits over WOPC	$147.8	$237.0	$259.9	$207.0	$233.3
Incremental Costs over WOPC	$19.0	$18.6	$21.5	$18.9	$18.4
Net Incremental Benefit	**$128.8**	**$218.4**	**$238.4**	**$188.1**	**$214.9**
Incremental Benefit / Incremental Cost Ratio	**7.8**	**12.7**	**12.1**	**11.0**	**12.7**

SECTION 10
NAVIGATION SYSTEM INVESTMENT PLAN

10.1 GENERAL

The formulation of a navigation system investment plan (SIP) for the Ohio River involves a combination of different investment opportunities. Each investment alternative increases the efficiency of the current navigation system and benefits the nation's overall transportation infrastructure.

10.2 FINDINGS TO DATE

Long term navigation needs on the Ohio include new lock chambers at the small, antiquated upper Ohio projects and the need to increase reliability at other Ohio River projects. The new lock needs along with a more aggressive maintenance strategy will, in the long run; reduce the NED costs associated with the operation and maintenance of the heavily vested and economically mature Ohio River mainstem navigation system.

10.3 NEED TO MONITOR

The findings in this draft report are sensitive to variability in both traffic demand forecasts and lock component reliability and make clear the need for continued updates of the necessary data and computer models to monitor future investment needs for the Ohio River. The economically justified investments result from the benefits of directing scarce resources to a more aggressive maintenance strategy at some Ohio River projects and conducting timely new lock construction on the upper Ohio.

10.4 ECONOMICALLY JUSTIFIED INVESTMENTS

The following tables summarize the economically justified project-level investments of the draft ORMSS SIP. Dates shown indicate the optimum timing of the justified investment. RM indicates a reactive maintenance or fix-as-fail strategy is optimum for a specific component. Reactive maintenance and component replacement strategies are an integral part of the Ohio River mainstem navigation system investment plan. The last table in this section summarizes investment priority needs.

Table 10-1 shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Emsworth is economically justified immediately in the study period (2010). The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Emsworth and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-1
Emsworth Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	**2038**	**2016**	RM	**2050**
Land Wall	**2012**	RM	**2014**	RM	RM
Middle Wall	**2011**	RM	RM	RM	RM
Upper Guide Wall	RM	RM	RM	RM	RM
Lower Guide Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	**2010**	**2010**	**2010**	**2010**	**2010**
Electrical Systems	New	New	New	New	New
	110 x 600	110 x 600	110 x 600	110 x 600	110 x 600

* Main Chamber is only used when the new 600' Aux is closed for maintenance. This is the reason for leaving the chamber in the reactive maintenance mode. If repairs are needed they will be made while the new lock is open.

Table 10-2 shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Dashields is economically justified immediately in the study period (2010). The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Dashields and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-2
Dashields Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	**2035**	RM	RM
Land Wall	**2013**	RM	**2010**	RM	RM
Middle Wall	RM	RM	RM	RM	RM
Upper Guide Wall	RM	RM	RM	RM	RM
Lower Guide Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Electrical Systems	**2011**	**2010**	**2010**	**2010**	**2010**
Upper Guard Wall	New	New	New	New	New
Lower Guard Wall	110 x 600	110 x 600	110 x 600	110 x 600	110 x 600

Table 10-3 shows a new 600' x 110' lock chamber to replace the existing 360' x 56' auxiliary chamber at Montgomery is economically justified immediately in the study period (2010) in four of the five forecast scenarios. In the NAAQS growth forecast scenario, a 1200' x 110' replacement of the auxiliary chamber is optimum. The table also shows main chamber component replacements to be traffic forecast sensitive. The draft ORMSS SIP recommends immediate feasibility level analysis for auxiliary lock chamber replacement at Montgomery and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments.

TABLE 10-3
Montgomery Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber *					
Miter Gate Machinery (Upper and Lower)	RM	RM	**2015**	RM	RM
Hydraulic Systems	RM	RM	**2015**	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	**2017**	**2015**	**2051**	**2035**
Land Wall	**2015**	RM	**2011**	RM	RM
Middle Wall	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	**2010**	**2010**	**2010**	**2010**	**2010**
Electrical Systems	New	New	New	New	New
River Wall	110 x 600	110 x 600	110 x 1200	110 x 600	110 x 600

* Main Chamber is only used when the new 600' Aux is closed for maintenance. This is the reason for leaving the chamber in the reactive maintenance mode. If repairs are needed they will be made while the new lock is open.

Table 10-4 shows the need to replace auxiliary miter gates at New Cumberland ranges from 2033 to 2039 depending on the traffic forecast scenario. Since the cost of replacing both sets of miter gates exceeds the $10.6 million threshold when considering fabrication, delivery, assembly, painting, and installation, it is listed as a major rehab. The table also shows economically justified proactive component replacement of the electrical systems in two forecast scenarios. Due to the longer term need of auxiliary gate replacement at New Cumberland, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-4
New Cumberland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	**2015**	**2015**	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Upper	**2037**	**2034**	**2034**	**2037**	**2037**
Miter Gate Lower	**2038**	**2035**	**2034**	**2038**	**2038**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-5 suggests the need at Pike Island to rehab the main chamber miter gates and electrical systems in the 2015-2016 timeframe. Other component replacements show traffic forecast sensitivity. The draft ORMSS SIP recommends a near-term major rehabilitation study of the main chamber miter gates and electrical systems at Pike Island and continued monitoring of traffic forecasts and other component reliability to optimize future investments.

TABLE 10-5
Pike Island Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates Upper Miter Gates Lower Electrical Systems	**2016** Rehab	**2015** Rehab	**2015** Rehab	**2016** Rehab	**2015** Rehab
Miter Gate Machinery (Upper and Lower)	RM	RM	**2014**	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Upper	RM	**2052**	**2052**	**2057**	**2056**
Miter Gate Lower	**2058**	**2053**	**2053**	**2058**	**2056**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-6 shows the need to rehab the main chamber miter gates and miter gate machinery at Hannibal ranges from 2011 to 2012 depending on the traffic forecast scenario. The table also shows economically justified proactive auxiliary miter gate replacement way out in 2065 in one forecast scenario. Due to the immediate need of main chamber rehabilitation at Hannibal, the draft ORMSS SIP recommends immediate action on a major rehabilitation study and continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-6
Hannibal Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2012**	**2011**	**2011**	**2012**	**2011**
Miter Gate Machinery (Upper and Lower)	Rehab	Rehab	Rehab	Rehab	Rehab
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate (Upper and Lower)	RM	**2065**	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-7 shows the need to rehab the main chamber miter gates and electrical systems at Willow Island ranges from 2027 to 2028 depending on the traffic forecast. Such timing suggests a more intermediate need. The finding at Willow Island leads the draft ORMSS SIP to recommend continued monitoring of traffic forecasts and component reliability at Willow Island to optimize future investments.

TABLE 10-7
Willow Island Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2027**	**2027**	**2027**	**2027**	**2028**
Electrical Systems	Rehab	Rehab	Rehab	Rehab	Rehab
Hydraulic Systems	RM	RM	RM	RM	RM
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-8 shows the need to rehab the main chamber miter gates, miter gate machinery, and electrical systems at Belleville in four of five traffic forecasts. The findings at Belleville lead to a draft ORMSS SIP recommendation of preparation for main chamber major rehabilitation project to begin study within the next 7 years and continued monitoring of traffic forecasts and component reliability to optimize future investments.

TABLE 10-8
Belleville Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2032**	**2017** Rehab	**2017** Rehab	**2017** Rehab	**2028** Rehab
Miter Gate Machinery (Upper and Lower)	RM				
Electrical Systems	**2010**				
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-9 shows the need at Racine to rehab the main chamber miter gates, miter gate machinery, and electrical systems in 2019 -2020. The relatively robust finding at Racine leads to a draft ORMSS SIP recommendation of continued monitoring of traffic forecasts and component reliabilities at Racine, in the near term with the intent of starting a major rehabilitation analysis in the medium term to optimize investments.

TABLE 10-9
Racine Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2020** Rehab	**2019** Rehab	**2020** Rehab	**2019** Rehab	**2019** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	**2050**	**2054**	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-10 shows the need to rehab the main chamber miter gates and electrical systems at Byrd ranges from 2030 to 2045 depending on the traffic forecast scenario. Such a range suggests more uncertainty and because of the less robust finding at Byrd Locks the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability at Byrd to optimize future investments.

TABLE 10-10
Byrd Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2055**	**2044**	**2045**	**2030**	**2033**
Electrical Systems	**2024**	Rehab	Rehab	Rehab	Rehab
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Auxiliary Chamber					
Electrical Systems	RM	RM	RM	RM	RM

Table 10-11 shows the need at Meldahl to rehab the main chamber miter gates, miter gate machinery, and electrical systems ranges from 2010 to 2013 depending on the traffic forecast scenario. Also, main chamber hydraulic systems shows economic justification in two traffic scenarios. The auxiliary chamber gates show economic justification for proactive replacement in all traffic scenarios. Since the cost of replacing both sets of miter gates would exceed $10.6 million when fabrication, delivery, assembly, painting, and installation is considered, this also qualifies as a major rehab. Given the relatively robust findings at Meldahl, the draft ORMSS SIP recommends starting both a main chamber and auxiliary major rehabilitation analysis at Meldahl while continuing to monitor traffic forecasts and component reliability of the main hydraulic systems order to optimize future investments.

TABLE 10-11
Meldahl Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2013** Rehab	**2010** Rehab	**2010** Rehab	**2010** Rehab	**2010** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems	RM	RM	RM	**2020**	**2015**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	**2010**	**2010**	**2010**	**2012**	**2010**
Hydraulic Systems	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	**2058**

Table 10-12 shows immediate need at Markland to rehab the main chamber miter gates and culvert valves in three of the five traffic forecast scenarios. The table also shows a long term need (2052) to do similar rehab work on the auxiliary chamber in one forecast scenario. Markland findings also show justification for proactive component replacement to be traffic forecast sensitive. Given the relatively robust findings at Markland, the draft ORMSS SIP recommends an immediate main chamber major rehabilitation analysis at Markland that includes the economically justified main chamber component replacements while continuing to monitor traffic forecasts and component reliability of the auxiliary lock components to optimize future investments.

TABLE 10-12
Markland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Base High
Main Chamber					
Miter Gates (Upper and Lower)	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valves	**2013**	**2013**	Rehab	Rehab	Rehab
Miter Gate Machinery (Upper and Lower)	RM	**2023**	**2024**	**2015**	**2015**
Electrical Systems	**2016**	**2016**	**2013**	**2013**	**2013**
Hydraulic Systems	**2036**	**2022**	**2020**	**2016**	**2016**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	RM	RM	RM	RM	**2052**
Culvert Valves	RM	RM	RM	**2045**	Rehab
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-13 shows economic justification at McAlpine for proactive replacement of main chamber culvert valves in 2010 and hydraulic systems in 2028-2030. Given this finding, the draft ORMSS SIP recommends replacement of the main chamber culvert valves at McAlpine for the near term and continued monitoring of traffic forecasts and main chamber component reliability to optimize future investments for all other components.

TABLE 10-13
McAlpine Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Hydraulic Systems	**2030**	**2030**	**2030**	**2030**	**2028**
Culvert Valves	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valve Machinery	RM	RM	RM	RM	RM

Table 10-14 shows the need at Cannelton to rehab the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, and culvert valves ranges from 2016 to 2017. Based on this finding at Cannelton, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability of the main chamber until such time a main chamber major rehabilitation analysis is warranted.

TABLE 10-14
Cannelton Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2017** Rehab	**2017** Rehab	**2016** Rehab	**2017** Rehab	**2017** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems					
Culvert Valves					
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-15 shows the need at Newburgh to rehab the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, and culvert valves ranges from 2016 to 2025 depending on the traffic forecast scenario. Based on this finding at Newburgh, the draft ORMSS SIP recommends continued monitoring of traffic forecasts and component reliability of the main chamber until such time a main chamber major rehabilitation analysis is warranted.

TABLE 10-15
Newburgh Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2025** Rehab	**2016** Rehab	**2016** Rehab	**2016** Rehab	**2016** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Hydraulic Systems					
Culvert Valves					
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

Table 10-16 shows the need at Myers to rehab the main chamber miter gates, miter gate machinery, electrical and hydraulic systems, culvert valves and culvert valve machinery ranges from 2011 to 2014 depending on the traffic forecast scenario. Based on this finding at Myers, the draft ORMSS SIP recommends near term preparation of a main chamber major rehab analysis while continuing to monitor traffic forecasts and component reliability of the main chamber to ensure optimal investment timing.

TABLE 10-16
Myers Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	**2014** Rehab	**2011** Rehab	**2013** Rehab	**2013** Rehab	**2013** Rehab
Miter Gate Machinery (Upper and Lower)					
Electrical Systems					
Culvert Valves					
Culvert Valve Machinery					
Hydraulic Systems					

Table 10-17 suggests the need to replace or totally rehabilitate the culvert valves of both chambers at Smithland in the near term. The table also suggests a long term need to replace miter gates. The finding at Smithland means the draft ORMSS SIP will recommend continued monitoring of component reliability in the short run at Smithland until such time the need for a component replacement becomes clearer.

TABLE 10-17
Smithland Locks Investment Plan

Chamber / Component	Clear Skies	Modified Clear Skies	NAAQS	Utility Based	Utility Based High
Main Chamber					
Miter Gates (Upper and Lower)	RM	**2054**	**2052**	**2054**	**2048**
Culvert Valves	**2013**	**2013**	**2013**	**2013**	**2013**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valve Machinery	RM	RM	RM	RM	RM
Auxiliary Chamber					
Miter Gates (Upper and Lower)	**2055**	**2050**	**2049**	**2050**	**2051**
Miter Gate Machinery (Upper and Lower)	RM	RM	RM	RM	RM
Hydraulic Systems	RM	RM	RM	RM	RM
Culvert Valves	**2010**	**2010**	**2010**	**2010**	**2010**
Culvert Valve Machinery	RM	RM	RM	RM	RM
Electrical Systems	RM	RM	RM	RM	RM

10.5 Summary of Priority Investment Needs

Table 10-18 summarizes priority investments necessary to economically and efficiently sustain Ohio River commercial navigation in the long run. The needs are defined as near-term, medium-term, and long-term. Follow-on feasibility level analysis will be required to authorize any investment decision.

TABLE 10-18
Priority Investment Needs

Investment	Year of Economic Justification
Near-Term (2010-2015)	
Emsworth New 600' Lock	2010
Dashields New 600' Lock	2010
Montgomery New 600' Lock	2010
Montgomery New 1200' Lock	2010
Markland Main Rehab	2010
Meldahl Main Rehab	2010-2013
Hannibal Main Rehab	2011-2012
Myers Main Rehab	2011-2014
Pike Island Main Rehab	2015-2016
Med-Term (2016-2025)	
Newburgh Main Rehab	2016-2025
Cannelton Main Rehab	2016-2017
Belleville Main Rehab	2017-2028
Racine Main Rehab	2019-2020
Long-Term (2026-2052)	
Willow Island Main Rehab	2027-2028
Byrd Main Rehab	2030-2045
Markland Aux Rehab	2052

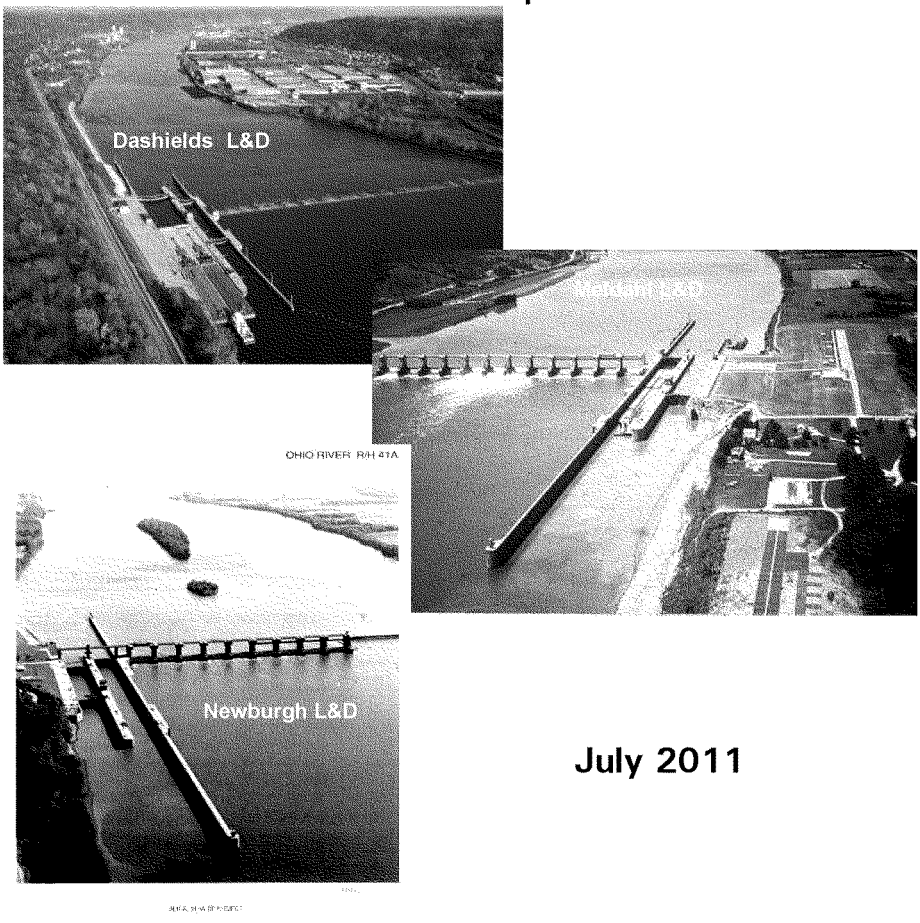
US Army Corps
of Engineers
Great Lakes and Ohio River Division
LOUISVILLE DISTRICT / HUNTINGTON DISTRICT / PITTSBURGH DISTRICT

Ohio River Mainstem Systems Study (ORMSS)

System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Environmental Appendix: Volume 1 of 2
Cumulative Effects Assessment Report



July 2011

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System Investment Plan/Programmatic Environmental Impact Statement

ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, and WEST VIRGINIA

Environmental Appendix: Cumulative Effects Assessment Report

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OHIO RIVER MAINSTEM SYSTEMS STUDY
Systems Investment Plan/Programmatic Environmental Impact Statement

Environmental Appendix
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Chapter 1
INTRODUCTION TO THE ORMSS CEA

1.1 CHAPTER OVERVIEW

The U. S. Army Corps of Engineers (Corps) is conducting a cumulative effects assessment (CEA) study as one part of an integrated System Investment Plan/Programmatic Environmental Impact Statement (SIP/PEIS) for long-term navigation needs and ecosystem sustainability needs on the mainstem of the Ohio River. This chapter provides an introduction to the CEA study. The section includes a brief description of the overall Ohio River study, the context for the environmental studies, the objectives and activities associated with the CEA study, and the contents of this report.

1.2 OHIO RIVER MAINSTEM SYSTEM STUDY

Waterway navigation facilitated by man-made structures has existed on the mainstem of the Ohio River for over 125 years. The 981-mile mainstem stretches from Pittsburgh, Pennsylvania, to Cairo, Illinois. In Pittsburgh, the Ohio River is formed at the confluence of the Allegheny and Monongahela Rivers; and at Cairo, the Ohio River flows into the Mississippi River. Mined natural resources such as coal and manufactured products such as petrochemicals are moved up and down the mainstem via towboats and various barge configurations. As such, waterway navigation has been and continues to be a vital link in the economic structure of the six contiguous states along the river (Pennsylvania, Ohio, West Virginia, Indiana, Kentucky, and Illinois). Waterway navigation on the Mississippi and on eight navigable tributary rivers expand the importance well beyond the six states. Further, such navigation is expected to remain a central part of commerce and economic growth in the region.

The design features, sizes, and locations of locks and dams on the Ohio River have evolved since the "wicket dams era" of a century ago. The Corps has been the lead federal agency since inception of the navigation system. At the current time, there are 19 "high-lift" locks and dams either on the river, under construction, or authorized. Each location is typically characterized by the presence of a main lock and a smaller auxiliary lock that is used during maintenance or rehabilitation periods for the main lock. Both locks may be used for recreational boats.

Several economic, engineering, and environmental issues are addressed in the current study, referred to as the Ohio River Mainstem Systems Study (ORMSS), to develop an investment plan for the navigation system to the year 2070. Economic issues are related to a range of projections of navigation traffic increases, and cost inefficiencies that occur due to barge queuing when main locks are subjected to maintenance or repair. Engineering issues relate to designs for increased sizes of auxiliary locks at several locations, and the development of risk functions that can be used to proactively schedule major repairs at existing facilities.

The SIP/PEIS includes several unique features that represent a more realistic approach for navigation system planning and management. First, it is widely recognized that "single number" projections of navigation traffic over several decades are problematic and fraught with uncertainties. The SIP/PEIS being developed includes five traffic forecasts through 2070. Further, the Ohio River Navigation Investment Model (ORNIM) is being used to develop numerous analyses of investment strategies based on combinations of assumptions related to navigation traffic levels, scheduling of routine lock and dam maintenance activities, and needs for major lock repairs or rehabilitation based on engineering risk analyses. As a result of anticipated uncertainties regarding navigation system needs and environmental consequences, it is recognized that the SIP/PEIS will require adjustment on a periodic basis. Such adjustments will be made in updated traffic projections, scheduling of investments, or maintenance priorities and will be documented through study reports and NEPA documents when appropriate for the changes under consideration. Finally, these features of the SIP/PEIS incorporate the concepts of adaptive management; i.e., monitor, evaluate, and adapt operational measures and practices.

1.3 CONTEXT FOR ENVIRONMENTAL STUDIES

Environmental issues have been addressed in a CEA study of the entire mainstem navigation system. This strategic-level impact study provides a holistic review of the past, current, and anticipated environmental impacts from multiple actions and programs of the Corps of Engineers; other federal, state, local governmental agencies; and private industries and agricultural activities. The CEA forms the technical basis for the Programmatic Environmental Impact Statement (PEIS) that has been prepared for the SIP/PEIS. The SIP/PEIS is an integrated report in that information required for an environmental impact statement pursuant to the National Environmental Policy Act (NEPA) are incorporated throughout the document rather than as a separate report.

Cumulative effects (CEs) are an emerging issue, in general, in impact studies; the definition that follows is in the Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) Regulations (Council on Environmental Quality, 1978):

> "Cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

This CEA study is in consonance with the above definition and with the policy of the U. S. Army Corps of Engineers relative to addressing the cumulative effects of water resources plans such as the SIP/PEIS. This policy is (EP 1165-2-1, U. S. Army Corps of Engineers, 1999):

> The cumulative effects of the plan and other similar activities should be analyzed. Each proposed water resource development activity is but a piece of a large-scale program. The combined beneficial and adverse economic, environmental and social impacts of individual projects, each of which may be relatively minor, can have a significant regional or national impact. At each level of the evaluation and review process it is necessary to assess the

> cumulative beneficial and adverse effects of individual project impacts. Significant effects should guide the decisions.

In addition to the CEA, two other issues are related to the context of environmental studies for the SIP/PEIS. The first involves the use of Environmental Sustainability (ES) as an "ultimate test" for determining the significance of cumulative effects. ES is identified in the Corps' recently published Environmental Operating Principles (EOPs). The second is associated with the usage of programmatic-level impact studies where water resources plans are being addressed. Both of these context issues are highlighted in this section.

1.3.1 Environmental Operating Principles

On March 26, 2002, General Robert Flowers, then Chief of Engineers of the Corps, announced seven EOPs for Corps planning and decision-making. Although all seven of the principles are applicable to the ORMSS, three are especially pertinent and have been incorporated in the CEA; they are (U. S. Army Corps of Engineers, 2002):

- Principle 1 -- Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse, and sustainable condition is necessary to support life.
- Principle 2 -- Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of Corps programs and act accordingly in all appropriate circumstances.
- Principle 5 -- Seek ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.

The foundation principle is number 1, which relates to sustainable development and environmental sustainability. An early definition of sustainable development was that it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). Stated differently, sustainable development involves the search for a path of economic progress that does not impair the welfare nor destroy the environmental and natural resources of future generations; thus intergenerational equity is a fundamental premise (Pearce, Markandya, and Barbier, 1989).

The above-three principles are addressed in a recent Engineering Circular (EC 1105-2-404) related to planning Civil Works projects consistent with ES considerations (U. S. Army Corps of Engineers, 2003). ES is defined as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations" (U. S. Army Corps of Engineers, 2002). While the EC indicates that it is applicable to feasibility and general reevaluation studies initiated after May 1, 2003, the concepts of ES were already being incorporated into the ORMSS. One relevant quotation from EC 1105-2-404 (U. S. Army Corps of Engineers, 2003) is:

> In accord with the environmental sustainability definition, "the Corps goal is to strive to achieve the appropriate balance between the economic and environmental benefits provided by a project. Currently, Corps projects can be developed to

achieve this goal through the formulation of plans that produce both national economic development benefits and national ecosystem restoration benefits. Where practical and supportable, the plan formulation should incorporate the principles of avoiding or minimizing significant adverse impacts within the guiding principle of limiting damage to the natural ecosystem. Through the incorporation of these principles, plans will likely avoid or minimize damages and be less intrusive. Thus, avoidance of disrupted natural processes is preferable, where practical, to creating new resources."

It is important to note that the EOPs, first announced by the Chief of Engineers in 2002, were incorporated in an Engineering Circular in May 2003, (EC 1105-2-404), and in Engineer Regulation (ER) 200-1-5 later in 2003 (U. S. Army Corps of Engineers, October, 2003).

1.3.2 Programmatic Environmental Impact Statements

Project-level environmental impact studies have been conducted for over 30 years in many countries. Since approximately 1990, there has been increasing attention directed toward strategic-level environmental impact studies in multiple countries. Strategic-level impact studies conducted in the United States are documented via the preparation of PEISs. The PEISs prepared in the United States are focused on environmental consequences of plans, programs, or policies of various governmental agencies. As noted above, a PEIS has been prepared for the SIP for the mainstem of the Ohio River. Further, in several other locations, the Corps has completed or is also involved in the preparation of PEISs for water resources plans or programs.

Strategic-level impact studies are typically characterized by larger geographical areas and longer future time frames than used at the specific project-level. Further, due to the paucity of consistent baseline data across the larger geographical area, and the possible complete absence of impact-related data on future projects and activities in the study area, the locational and quantitative specificity of impact predictions tends to be less than for project-level studies. However, despite these differences, strategic impact studies and associated PEISs provide the opportunity to more appropriately address cumulative effects from multiple actions and activities across space and time; to delineate geographical areas, habitat types, and plant and animal species which should be afforded more protection; and to require certain impact mitigation strategies and programs for enhancing ES. Further, the planning and implementation of adaptive management programs can be integrated into PEISs. Beyond these potential benefits, the opportunity exists for introducing environmental issues and concerns at the decision level which is often driven only by traditional engineering and economic analyses, and related non-environmental policy choices.

More specifically, the PEIS for the SIP being developed via the ORMSS addresses the direct, indirect, and cumulative effects of the plan itself. The SIP/PEIS is an official plan prepared by the Corps of Engineers which will guide or prescribe alternative means to maintain an efficient, economically viable, and environmentally compatible navigation system, and which will provide information upon which future Corps actions will be based. However, it should be noted that future environmental assessments (EAs) or EISs will be prepared, as appropriate, on specific actions included within the SIP/PEIS. Such future documentation is based upon the concept of tiering. Tiering is described in Section

1502.20 of the CEQ NEPA Regulations as follows (Council on Environmental Quality, 1978):

> Agencies are encouraged to tier their environmental impact statements to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review. Whenever a broad environmental impact statement has been prepared (such as a program or policy statement) and a subsequent statement or environmental assessment is then prepared on an action included within the entire program or policy (such as a site specific action) the subsequent statement or environmental assessment need only summarize the issues discussed in the broader statement and incorporate discussions from the broader statement by reference and shall concentrate on the issues specific to the subsequent action. The subsequent document shall state where the earlier document is available. Tiering may also be appropriate for different stages of actions.

Further, and as implied above, it will be necessary to periodically review the SIP/PEIS and PEIS in order to maintain current navigation and environmental information that can inform specific project-level decision-making. Such reviews can be aided by monitoring and policy information generated by an on-going adaptive management program. Depending upon the types of modifications to the SIP/PEIS, it may be necessary to issue one or more Supplemental PEISs at future dates.

1.4 GOALS AND ACTIVITIES OF THIS STUDY

The goal of the CEA is to assess the full direct, indirect, and contributed impacts of further modernization of the Ohio River mainstem navigation system on resources, ecosystems, and human communities along the mainstem. The analysis addresses the accumulation of meaningful impacts to environmental resources from maintenance and modernization of the navigation system in concert with impacts from other past, present, and reasonably foreseeable future actions (RFFAs) by the Corps of Engineers and others.

Multiple activities were associated with conducting this CEA study. For example, an eight-person group consisting of four persons from the Corps and four persons from an associated consulting firm (Woolpert, Inc.), periodically met to plan, discuss, review, and synthesize information. This group also periodically met with a 40-person Interagency Working Group (IWG) to discuss status reports and to seek input and participation in various study features. Further, 12 public scoping meetings were held to seek input on the scope and issues of concern related to the CEA.

Considerable effort was expended in the identification and procurement of pertinent information and reports. Identification was achieved through web-based searches of topics and agency reports. Traditional scientific searches of books and journals were also made. Numerous telephone and email communications were used to identify pertinent agency reports and data related to the Ohio River mainstem. As these various documents were procured, they were categorized by the topics to be addressed in this study. The documents were then reviewed for specific relevance and the pertinent information was extracted for subsequent use in this CEA.

A unique feature of this CEA was specific data gathering via field surveys (e.g., bathymetry and bottom substrate characteristics for use in a navigation traffic-fish effects model named NAVPAT). Further, specific research efforts were conducted for mussel resources, wintering habitat requirements for fishes, and upstream and downstream migration of fish species through existing locks and dams. The results of these surveys and research efforts have been incorporated herein.

A major activity involved the integrated analysis of the assembled information and data related to past, present, and potential future cumulative effects on key resources, ecosystems, and human uses and communities within and along the Ohio River mainstem. The key resources include water and sediment quality, mussels, fish, riparian/floodplain areas, recreation, and health and safety. An ecosystem perspective was used for riparian/floodplain resources, with this category also including wetlands, islands, and soils and geology. Consideration of potential effects on protected species is incorporated within appropriate chapters rather than as a separate chapter. Human uses and communities relate to navigation traffic, health and safety, river-based recreation, socioeconomics, and cultural resources. Individual chapters have been prepared on these resources, ecosystems, and human uses and communities. Internal and external reviews were incorporated in the preparation of each chapter.

1.5 CONTENTS OF THIS REPORT

This CEA report is organized into 13 chapters and five exhibits. Utilized references are listed, as appropriate, at the end of each chapter or exhibit. Following this introductory chapter, Chapter 2 summarizes the overall project approach, methodology, and findings for each resource type or Valued Environmental Component (VEC). Chapters 3 through 12 focus on the CEs from past, present, and future actions on ten identified VECs. Chapters 3 through 6 address the VECs related to aquatic and riparian ecological resources. For example, Chapters 3 through 5 relate to three subcomponents within aquatic ecological resources (water quality and sediment quality, fish, and mussel resources, respectively). Chapter 6 focuses on the riparian/floodplain resources VEC; including three functional categories involving hydrology and sediment dynamics, biogeochemistry and nutrient cycling, and habitat and food web maintenance. Threatened and endangered species are addressed, as appropriate, within Chapters 4, 5, and 6.

Chapters 8 and 9 are associated with human uses of aquatic and riparian ecological resources, with Chapter 8 addressing the health and safety VEC, including fish consumption advisories resulting from contaminant uptakes from the water and sediment phases. Chapter 9 highlights the river-based recreation VEC, with such recreation including boating, fishing, and multiple uses of the riparian zone. Because a primary focus of ORMSS is related to navigation investment actions, Chapter 10 addresses historical navigation traffic and projected trends under several scenarios. Chapters 7, 11, and 12 are broadly related to human uses of the Ohio River mainstem and its environs, with Chapter 7 addressing the air quality resources VEC. Chapters 11 and 12 encompass the socioeconomic and cultural resources VECs, respectively.

Chapter 13 discusses Adaptive Management and Monitoring approaches that may be applicable to integrated, long term strategies for management of Ohio River resources. The five exhibits include Exhibit A, Procedure and Special Methods, which delineates the key features of the process and special methods used to identify, analyze, and synthesize

information related to this study. Additional exhibits include a report on the public scoping process and an analysis and projection of land use patterns.

1.6 REFERENCES

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Chapter 2
CEA SUMMARY CHAPTER

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2.2 INTRODUCTION

This chapter summarizes the findings of a Cumulative Effects Assessment (CEA) conducted to address environmental issues related to development of the System Investment Plan/Programmatic Environmental Impact Statement (SIP/PEIS) for the Ohio River Mainstem Systems Study (ORMSS). The CEA was developed as a strategic-level impact study which provides a holistic synthesis of past, current, and anticipated environmental impacts from multiple actions and programs of the Corps of Engineers; other Federal, state, and local governmental agencies; and others (e.g., private industries and agricultural activities). In addition to synthesizing the impacts of multiple actions, such strategic level studies consider time and space dimensions and delineate geographical areas, habitat types, and plant and animals species which should be afforded special protection while also identifying certain impact mitigation strategies and programs for

enhancing Environmental Sustainability (ES). Further, the planning and implementation of adaptive management programs can be integrated into such studies.

As stated in Chapter 1 **INTRODUCTION TO THE ORMSS CEA,** cumulative effects (CEs) are becoming increasingly important in environmental impact studies. The CEA for ORMSS adhered to CEQ's NEPA's definition:

> "Cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (Council on Environmental Quality, 1978).

The ORMSS CEA is also in consonance with Corps' policies and approaches, including those outlined in the Environmental Operating Principles (EOPs) (USACE 2002), which are discussed in more detail in Chapter 1 of the CEA.

The specific goal of the CEA was to assess the full direct, indirect, and contributed impacts of further modernization of the Ohio River mainstem navigation system on the resources, ecosystems, and human communities along the mainstem. The study, however, went beyond this goal to consider Environmental Sustainability (ES), defined in the EOPs as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations." Regarding ES, the CEA 1) explored ES as an "ultimate test" for determining the significance of cumulative effects and 2) identified types of actions necessary to achieve ES.

2.3 CEQ METHODOLOGY AS APPLIED TO THE ORMSS CEA

This section summarizes an 11-step procedure, promulgated by the CEQ, for planning and conducting impact studies of cumulative effects. Within this framework, four special methods were developed and applied to conduct the ORMSS CEA. These methods, adapted to the 11 steps, were:

- a continuous scoping process designed to determine the scope of the CEA and significant issues to be addressed
- the development of matrices that relate the potential impacts of reasonably foreseeable future actions (RFFAs) to initially12 Valued Environmental Components (VECs) and their subcomponents
- an analysis approach for determining the past, present, and future ES conditions of the VECs and subcomponents, and
- a method that relates to delineating actions required to attain ES. Such actions also are referred to as "ES needs".

Further details on these methods are included in CEA Report, Exhibit A – Procedure and Special Methods. **Table 2-1** presents the 11-step CEQ general framework, followed by a detailed stepwise explanation of how the four methods were applied to conduct the

ORMSS CEA. The four methods are shown in **bold** when first introduced in the narrative for the 11-step framework.

TABLE 2-1
The CEQ Framework

EIA Components	CEA Steps
Scoping	1) Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals.
	2) Establish the geographic scope for the analysis.
	3) Establish the time frame for the analysis.
	4) Identify other actions affecting the resources, ecosystems, and human communities of concern.
Describing the Affected Environment	5) Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to changes and capacity to withstand stresses.
	6) Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds.
	7) Develop a baseline condition for the resources, ecosystems, and human communities.
Determining the Environmental Consequences	8) Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.
	9) Determine the magnitude and significance of cumulative effects.
	10) Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects.
	11) Monitor the cumulative effects of the selected alternative and adapt management.
SOURCE: Council on Environmental Quality, 1997.	

While the steps listed in the table should be viewed as components of a cohesive process, they are organized under the basic components of environmental impact assessment. Steps 1 to 4 relate to scoping, Steps 5 through 7 to describing the affected environment, and Steps 8 through 11 to determining the environmental consequences.

- CEQ Step 1 – Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. This step identified typical impacts associated with the construction and operation of navigation system locks and dams, and their repair, rehabilitation and periodic maintenance activities. Public scoping meetings were held along with several meetings of a 40-person Interagency Working Group (IWG) that met throughout the development of the CEA. The membership of the IWG consisted of representatives from several federal and state agencies responsible for environmental and natural resources management, and three non-governmental organizations. The IWG participated throughout the CEA study and consequently, provided **continuous scoping**. The initial scoping in Step 1 provided the basis for the identification of 12 VECs of concern. The 12 original VECs were aquatic ecological resources (including water and sediment quality, mussels, and fish as subcomponents), riparian and floodplain resources (including floodplain hydrology, terrestrial habitat, wetlands, islands, and soils and geology as subcomponents), threatened and endangered species

(including fish, mussels, mammals, birds, and plants), air quality, recreational uses of the river, noise, aesthetics, human health and safety, cultural resources, transportation and traffic, land use, and socioeconomic resources (including environmental justice).

- Step 2 – Establish the geographic scope for the analysis. The geographic scope for the majority of the identified CE issues and related VECs consisted of the mainstem of the Ohio River along with its 500-year floodplain. When data were available on actions, resources, and impacts, the geographic scope often focused on the mainstem and the contiguous counties in the six states along the mainstem.

- Step 3 – Establish the time frame for the analysis. The selected time frame was typically from 1920 to 2070 for most VECs. The earlier date coincides with the initiation of locks and wicket dams on the Ohio River mainstem. The latter date encompasses the economic study period for the current SIP/PEIS. One exception for this time frame was the inclusion of information on much earlier cultural sites for the cultural resources VEC.

- Step 4 – Identify other actions affecting the resources, ecosystems, and human communities of concern. As noted in the cumulative effects definition in the introduction to this chapter, "other actions" include past, present, and Reasonably Foreseeable Future Actions (RFFAs). To more fully assess these actions and their potential effects, a series of 22 RFFA matrices were developed. The 22 matrices encompassed the 12 VECs and their subcomponents as delineated in Step 1. The RFFAs, which also included similar past and present actions, were defined as:

  > Actions identified by analysis of formal plans and proposals by public and private entities that have primary (direct) or secondary (indirect) impacts on VECs associated with the Ohio River. RFFAs also include potential actions that are beyond mere speculation when incorporated in plans or documents by credible private or public entities. RFFAs may also include events forecasted by trends, probable occurrences, policies, regulations, or other credible data that may have bearing on the VECs (adapted from CEQ 1997).

  Through the combined efforts of the project planning team and the IWG, a total of 87 RFFAs were identified and considered in the CEA; the types were divided into six categories: 1) navigation investment actions, 2) other Corps actions, 3) "but for" actions (actions that would not occur "but for" the existence of the navigation system), 4) actions by others, 5) natural disasters, and 6) regulatory environment. Each listed RFFA was characterized in terms of its anticipated time period of occurrence, probability of occurrence, and location on the river. The anticipated effects of each RFFA on each VEC or subcomponent were described and recorded. Finally, the importance (high, medium, or low) of each RFFA relative to CEs on each VEC or subcomponent was described and recorded.

  Many sources were consulted to identify and describe the RFFAs including ORSANCO data, EPA air quality data, census data, scientific literature, Corps studies and documentation for the Myers and Greenup projects and the Environmental Restoration Program (ERP), as well as navigation projections and other studies by the Corps' Economics Group.

- Step 5 – Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. This step was based upon an analysis of environmental sustainability (AES) for the pertinent VECs or subcomponents. The AES approach was comprised of four parts: 1) identification of "common effects" on the VEC or its subcomponent from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix (Step 4 above); 2) selection of indicators of environmental sustainability (ES) for the VEC or its subcomponent, and their tiered grouping, as appropriate; 3) description of the "connections" between the common effects (and related High and Medium importance RFFAs) and the indicator groups; and 4) assignment of a "bottom line" determination of the ES of the VEC or subcomponent, based on considering the past, present and future conditions. The ES categories included "not sustainable", "marginally sustainable", and "sustainable". Specific ES conditions were developed for each VEC or subcomponent.

- Steps 6 and 7 – Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds; and define their baseline conditions. These two steps were addressed jointly for each VEC or subcomponent. The approach consisted of identifying historical and current laws, regulations, ordinances, and programs that contain regulatory thresholds and/or policies related to the VEC or subcomponent. Then, historical reference point and trends information, along with current conditions, were summarized for the ES indicators for the VEC or subcomponent. Numerous information sources were reviewed for Steps 6 and 7. Further, the institutional information and environmental conditions and compliance with regulatory thresholds served as the basis for the categorization of the past and present ES for the VEC or subcomponent.

- Step 8 – Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. This step was largely accomplished through the development of the RFFA matrices as described in Step 4. Further, peer-reviewed literature, various governmental studies and reports, and impact-study related and resource-management related books were used to more thoroughly document numerous relationships. Attention was also given to various interactions between VECs and subcomponents (e.g., what are the implications of changes in water quality on the populations of mussels in the river?).

- Step 9 – Determine the magnitude and significance of cumulative effects. Due to limited data on specific impacts from various actions, and to the system-wide focus of the CEA study, it was not possible to quantitatively determine the magnitude of the cumulative effects on the VECs and subcomponents. Rather, a qualitative determination was made based on the AES approach described in Step 5. The significance of the cumulative effects was ascertained via compliance or noncompliance with regulatory thresholds, and the consideration of the connections between common effects and indicators of ES. The assigned categories of ES for the past, present and future represent the composite significance determination for the CEs on each VEC or subcomponent.

- Step 10 – Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. This step was addressed via the identification of generic mitigation measures for many of the analyzed actions, with particular attention given to navigation investment actions by the Corps. In addition, various regulatory programs that can facilitate or are expected to emphasize generic mitigation measures for numerous actions also were identified and incorporated into the analysis. Further, the fourth special method used in this CEA delineated a process to identify various mitigation and other ES needs for two of the most significant Ohio River resources – the aquatic ecological and riparian/floodplain resources.

- Step 11 – Monitor the CEs of the selected alternative and adapt management. This step was addressed systematically for each VEC and subcomponent. The key criteria used to "trigger" Step 11 were the past, present, and future ES categories for the VECs and subcomponents. If the VEC or subcomponent was currently categorized as "sustainable", and this is expected to continue into the future, only targeted additional monitoring over that currently being done is recommended, and no specific adaptive management strategy will be developed. For VECs or subcomponents that are currently categorized as "not sustainable", or "marginally sustainable", specific collaborate monitoring will be recommended along with an appropriate adaptive management strategy.

Although the CEQ guidance provides distinct steps, the steps were adapted to create a relatively seamless process to attain the ORMSS' CEA goal of providing a comprehensive and integrated understanding of the numerous actions and issues that have shaped and will continue to shape the environment of the Ohio River mainstem.

2.4 SPECIAL CEA-RELATED STUDIES

As the CEA study progressed, it was realized that additional research studies, surveys and databases would be necessary to support well grounded CEs assessments, make ES determinations, and identify ES needs that might be further studied in an adaptive management program. The results of these surveys, research efforts and special reports were incorporated into the main chapters of the CEA or as appendices. Following is a list of these special studies and their placement in the CEA:

Research studies included:

- A study of various engineering and hydraulic factors related to Ohio River locks and dams, along with fish swimming velocities of 44 target species. The objective of this study was to assess upstream fish-passage opportunities through Ohio River mainstem dams by relating historical hydraulic conditions at the dams to swimming capabilities of select native and non-native fishes to determine if the dams are restricting upstream movements of fishes. Additionally, abundance and distribution of target species were examined in relation to upstream fish-passage opportunities. The study suggests that upstream fish passage opportunities generally occur during open-river conditions, when dam gates are lifted clear of the water and are no longer controlling water levels at the dams. The general spatial pattern of

open-river indicated that the potential for fish passage is low to high at dams in the Louisville District, low to moderate at Huntington District dams, and low at Pittsburgh District dams. In general, open-river conditions were more frequent during higher flows of winter and spring and generally nonexistent during lower-flows of summer and fall. (Additional information is included in the CEA Chapter 4 – Fish, and in Aquatic Studies Exhibit A – Fish Passage (USGS).

- A study of winter habitat types used by fishes in the Smithland and Belleville navigation pools, and comparison of the results between the downstream and upstream pools. The objective of this study was to examine how abiotic characteristics (e.g., channel morphology, latitude, depth, etc.) regulate winter habitat use of critical fish species in the Ohio River. The two-year research project focused on a lower pool (Smithland – RM 846 to 918) and an upper pool (Belleville – RM 162 to 204) of the Ohio River. The study found distinct differences between the pools relative to species richness and winter habitat use. Connectivity between tributary habitats and mainstem habitats appeared to be important to winter success of fishes. Island backwaters appeared to be particularly important for fishes during winter, providing flow breaks and shelter from barge activity. Further insights of the study are included in the CEA Chapter 4 – Fish, and in Aquatic Studies Exhibit B – Winter Habitat (Southern Illinois University).

- A review and analysis of the Corps' statutory authorities, policies, regulations and guidance for mitigation of historical environmental damages from Corps projects and actions by others, and for mitigation of proposed Corps projects, plans, and/or programs. The results are summarized in CEA Exhibit A – Procedure and Special Methods.

Databases developed included:

- An in-depth compilation of basic literature and historical data on mussel species in the navigation pools of the Ohio River mainstem. The database, available on a CD, includes mussel species by Ohio River pool, known fish hosts for mussels by pool, and information on establishment of zebra mussels in the Ohio River, as well as common names for mussels and fishes. The database was used in development of CEA Chapter 5 – Mussels and presented in Aquatic Studies Exhibit I – Mussels Database (OSU).

- The collection of data on bottom substrates and bathymetry for navigation pools in the Ohio River mainstem for the Navigation Predictive Analysis Technique (NAVPAT) model. The goal of NAVPAT is to provide quantitative results, which can assess tow induced changes in aquatic habitat quality for a specific area of a river cross-section or an entire reach of river. NAVPAT incorporates 15 life stages of fishes to link tow movements to possible biological effects. Further details are provided in CEA Chapter 4 – Fish and in the NAVPAT Report.

Other special studies included:

- Under the Endangered Species Act (ESA), a Section 7 Biological Assessment (BA) related to continued navigation system operational practices and effects on threatened or endangered plant and animal species within or near the Ohio River mainstem. The primary objective of the BA is to facilitate consultation with the USFWS in compliance with the Endangered Species Act. It presents detailed information to assess effects to 18 listed Threatened and Endangered (T&E) species from operation and maintenance activities on the Ohio River and its commercially navigable tributaries, including two mammal, two bird, one fish, one crustacean, nine mussel and three plant species. The Section 7 BA is not part of the CEA Report, but is included in the Environmental Appendix of the SIP/PEIS.

Four additional studies undertaken for ORMSS related to fish movement and passage in the Ohio River were conducted by the West Virginia Department of Natural Resources in coordination with the Ohio River Fish Management Team (ORFMT). Another related fish study listed below was conducted by Tennessee Technological University, Cookeville, Tennessee.

- The Fish Passage Direct Observations Study surveyed fish community structures at lock chambers and in tailwaters and studied hydrologic conditions that promote fish passage and short-term movement patterns of targeted species at the Winfield Locks and Dam on the Kanawha River.

- The Fish Tagging and Recovery Study examined fish movement in the Ohio River along with hydrologic conditions that stimulated movement based on fish tagging and tag return data.

- Studies of recreational angling efforts were conducted at eight tailwaters along the Ohio River mainstem and compared current angling activities with results from similar previous studies.

- The Glochdial Infestation Study collected fish from ten areas to determine rates of glochial (juvenile mussel) infestation of host fish and ascertain potential impacts of restricted fish passage on host/mussel relationships.

- The Lipid and Fatty Acid Survey analyzed fatty acid profiles of migratory fish from six pools to determine if genetic variations occurred among different populations.

The results of these five studies are summarized in the discussion on fish passage in Chapter 4 of the CEA and in Aquatic Studies, Exhibit D.

2.5 ORGANIZATION OF VALUED ENVIRONMENTAL COMPONENTS (VECs) AND CEA CHAPTERS

The continuous scoping process applied to the CEA led to the reorganization of the original 12 VECs into 10 substantive VEC chapters. Noise and Aesthetics, originally listed as separate VECs were incorporated into the Health & Safety and Recreation

chapters, respectively. Land Use, also formerly a separate VEC, was considered in a detailed supplemental appendix to the Socioeconomics chapter. Information on threatened and endangered (T&E) species was integrated into relevant sections on species and biotic communities, with special emphasis on the endangered mussels of the Ohio mainstem.

Reorganization of the VECs led to development of 10 chapters for the CEA, as follows: Key resources include **1) water and sediment quality, 2) mussels, 3) fish, 4) air quality**. An ecosystem perspective was used for **5) riparian/floodplain resources**, with this category also including wetlands, islands, riparian forests, and soils and geology. Human uses and communities are related to navigation **6) transportation and traffic**, **7) health and safety**, **8) river-based recreation**, 9) **socioeconomics** and **10) cultural resources**. Work plans developed early in the CEA process provided a framework for assembling and analyzing pertinent information for each VEC chapter. Typical contents of the VEC chapters included:

- Definition of VEC and its Subcomponents
- Objectives and Scope of the VEC Study
- Issues from Scoping
- Indicators of Environmental Sustainability
- Laws, Regulations, Ordinances, and Programs
- Past to Current Baseline Conditions for the VEC and its Subcomponents
- Special Information Related to the Ohio River
- Interactions with Other VECs
- Relevant Actions Affecting the VEC and its Subcomponents
- Cumulative Effects and Environmental Sustainability
- Summary and Conclusions
- References

Of the ten VEC chapters prepared, the review process identified six that were of higher priority: Water and Sediment Quality, Fish, Mussels, Riparian/Floodplain Resources, Health and Safety, and Recreation.

2.6 PROJECT DEVELOPMENT ORGANIZATION

Three groups worked together from the early stage of the CEA to its final development and review: a Central Planning Team (CPT), an Oversight Board (OB), and

the previously mentioned IWG. Information on the roles and composition of these groups is included in **Table 2-2** and presented in further detail in Exhibit A.

TABLE 2-2
Key Groups in Developing the ORMSS CEA

Component	Key Functions	Composition/ Meeting Frequency
Central Planning Team (CPT)	Provided leadership to the entire CEA process; including educational features related to CEA; interactions with the OB and IWG; development of VECs, RFFAs, methods, and AES; and syntheses and internal review of information.	Consisted of 7 members – 3 persons from the Corps and 4 persons from a consulting firm; representing several disciplines; met every 2 - 3 months throughout project
Steering Committee --- Oversight Board (OB)	Provided policy advice and overall approvals for scheduling and budgetary matters for the entire ORMSS.	14-person group comprised of Corps management–level professionals from the pertinent Division and 4 Districts
Interagency Working Group --- (IWG)	Provided scientific and/or policy information to the CPT; aided in identifying research needs; participated in the completion of RFFA matrices, the identification of indicators for AES, and the delineation of ES needs; and reviewed various study documents.	Approximately 40 members from Federal and state agencies and NGOs. Organizations represented included U.S. Fish & Wildlife Ser., U.S.EPA, ORSANCO, State Departments of Natural Resources, Nature Conservancy and Ohio River Foundation.

2.7 ELEMENTS COMMON TO ALL VEC ANALYSES

Each VEC chapter contains detailed information related to the CEA processes of scoping and describing the affected environment. As this information was collected and analyzed, it was used to determine each VEC's past, present, and future environmental sustainability (ES). Further, this information and input from members of the IWG were used to outline actions needed to move toward higher levels of ES for some VECs. As discussed in the previous section on organization, the VEC chapters had a common framework, enabling the preparation of cross-reference tables to summarize some elements common to analyses of all VECs. Such cross-referencing is useful in illustrating the far-ranging connections between and among VECs.

Legal measures and government programs are common to all VECs. **Table 2-3** lists more than 60 laws, regulations and programs applicable to the overall CEA and uses shading to illustrate their primary or secondary relevance to each VEC. At least 10 such laws, regulations and programs are cross-cutting, with shadings applied to six or more VECs. NEPA is the most far-ranging measure listed, affecting every VEC. In general, the denser shading pattern for the columns for aquatic ecological resources (water & sediment quality, fish and mussels), riparian resources, and health and safety illustrate the interrelatedness of these VECs. Relationships among the remaining VECs also occur, but distinct patterns are less apparent.

TABLE 2-3
Cross-Reference of Laws, Regulations and Programs Applicable to VECs in the ORMSS CEA

Laws, Regulations and Programs	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
Abandoned Shipwreck Act										
Archaeological & Historic Preservation Act										
Archaeological Resources Protection Act										
Civil Rights Act, Title VI										
Clean Air Act										
Clean Water Act										
COE Permitting Statutes (listed below)										
Sec. 10 (obstructions in nav. waters)[1]										
Sec. 404 (dredged & fill materials)[2]										
Emergency Planning & Community Right-to-Know Act (a.k.a. SARA Title II										

[1] Section 10 is a provision of the River and Harbor Act.
[2] Section 404 is a provision of the Clean Water Act.

Laws, Regulations and Programs	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
Emergency Wetlands Resources Act										
Endangered Species Act										
Executive Orders:										
11988 (floodplain mgmt.)										
11990 (wetland protection)										
12898 (environmental justice)										
13112 (invasive species)										
13274 (transportation project review)										
13287 ("Preserve America")										
13186 (protection of migratory birds)										
Farm Security & Rural Investment Act 2002 Farm Bill)										
Farmland Protection Policy Act										
Federal Water Project Recreation Act										
Fish & Wildlife Act										
Fish & Wildlife Conservation & Water Resources Development Act										
Fish & Wildlife Coordination Act										
Flood Control Act of 1944										
Hazardous Materials Transportation Act										
Historic Sites Building & Antiquities Act										
Inland Waterways Revenue Acts										
Kentucky Mussel Refuges Act										
Migratory Bird Conservation Act										
Migratory Bird Treaty Act										
National Environmental Policy Act (NEPA)										
National Flood Insurance Acts										
National CSO Control Policy										
National Historic Preservation Act										
National Invasive Species Act										
National Trails System Act										
National Wildlife Refuge System Admin. Act & National Wildlife Refuge System Improvement Act										

Laws, Regulations and Programs	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
Native American Grave Protection & Repatriation Act (NAGPRA)										
Noise Control Act										
North American Wetlands Conservation Act										
Occupational Safety & Health Act										
Oil Pollution Act										
ORSANCO monitoring										
Phase 1 & 2 NPDES Program (stormwater)										
Pollution Prevention Act										
Quiet Communities Act										
Reclamation Recreation Mgmt. Act										
Recreational boating safety regulations and programs										
Refuge Recreation Act										
Rivers and Harbors Act										
Sec. 7 (promulgation of nav. regs)										
Sec. 107 (small navigation projects)										
Safe Drinking Water Act										
Site remediation statutes, including CERCLA, RCRA & SARA										
Spill response										
State cultural resources regulations										
State fishing regulations										
State water quality certification										
Toxic Substances Control Act										
TMDL program										
Transportation Equity Act (TEA-21)										
Water Resources Development Acts (WRDA)										

Key to shading: Indicates primary relevance to a VEC.
Indicates secondary relevance to a VEC.
No shading indicates non-applicable.

Reasonably foreseeable future actions (RFFAs) are a second CEA element common to all VECs. **Table 2-4** cross references the RFFAs for ORMSS and their positive or

negative effects by VEC. As with **Table 2-3,** the emergence of a darker shading pattern on the left side of **Table 2-4** illustrates the interrelatedness of the six VECs assigned higher priority.

The third important common element was the identification of specific indicators of ES for each VEC. Such indicators provide benchmarks for measuring CEs on a given resource. Consequently, well chosen indicators can be used to make connections between multiple actions and the condition of a VEC and to facilitate analyses of past, present, and future ES.

TABLE 2-4
RFFAs Ranked High and Medium and their Effects by VEC

RFFA	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
Navigation Investment Actions										
Lock Extensions/New Locks/Replacement or Rehabilitation		-	-	-	+	+	-	+	-	H/M+
L&D operation and maintenance	-	-	-		+	+		+	-	
Non-structural navigation improvements		+			+	+	+	+		
Dam replacement and rehabilitation		-	-	-	+	+		H/M+	-	
Other Corps Actions										
Channel dredging/dredged material disposal	-	-	-			-			-	
Navigation aids - Construction and O&M					+					
Flood damage reduction projects										
levees/floodwalls		-		-	+	-			-	+
dry dams, other projects off mainstem	-	-		-	+	+		+		
channel modifications		-	-	-	+					
nonstructural measures (e.g. relocation)		+	+	+		+				
Emergency streambank stabilization (Sec. 14)		-	-		+					
Modification of Corps structures for environmental improvements (Sec. 1135)		+	+	+		+			-	
Environmental restoration of aquatic ecosystems (Sec. 206)		+	+	+		+				
Recreation facilities - Construction and O&M					+	+		-		+
ERP Projects - 5 categories	+	+	+	+		+				H/M+
Port development (Sec. 107) and maintenance dredging	-	-	-	-	-	-	-	+	-	H/M
Pool maintenance		-	-	-	-	+				-
"But for" Actions										
Commercial Navigation										
barge queuing		-	-		-		-	-		-
fleeting areas/barge storage	-	-	-		-	-	-		-	H/M-
terminals	-	-	-	-	-	-	-	+	-	H/M
multi-modal sites	-	-	-	-	-	-	-	+	-	H/M

RFFA	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
increased traffic	-	-	-	-	-	-	-	+		
dispersed barge traffic		-	-	-	-	-				
barge/tow tech/"green" design			+		+					
accidents/spills	-	-	-		-	-				
Coast Guard Nav. Aids - Constr'n.,O&M					+	+				
Instream sand and gravel mining	-	-	-	-	-		-		-	
Floodplain sand and gravel mining	-		-	-			-		-	
Limestone aggregates mining			-	-			-		-	
Coal utilities	-	-	-	-	-		-	+	-	
Other coal industries	-	H/ M-	-	-	-		-	+	-	
Hydropower on dams		-	-	-	-	-				
Water intakes			-							
Industrial users, excluding coal-related	-	-	-		-		-	+		
Recreation facilities - Construction and O&M			-		+	+		-		+
Actions by Others										
Public lands acquisition and management		+	+	+		+				
Floodplain development										
residential		-	-	-	-		-		-	
commercial		-	-	-	-	-	-		-	
industrial	-	-	-	-	-	-	-		-	H/M
Private recreational sites, including camp-grounds, docks, and seasonal trailer parks				-		+			-	
Crossings										
bridges		-	-	-	-				-	H/M
utility		-	-		-				-	
industrial		-	-		-				-	
Riverbed crossings		-	-		-					
Marina development & operation	-	-	-		-	+		-	-	H/M
Water -based recreation										
boating					-	+		-		+
fishing		-			-	+		-		+
PWCs					-	+		-		
hunting					-	+				
wildlife watching						+				+
sight-seeing						+				+
Silviculture			-			+			-	
Agriculture	-	-	-	-	-				-	+
WWTP discharges										
municipal		-	-		-	+				
industrial	-	-	-		-	+				
onsite systems		-	-		-	-				
Stormwater discharges	-	-	-		-	-				-
Brownfields redevelopment		+			+	+				
Trail/bikeway development						+				
Casinos									-	

RFFA	WQ & SQ	Fish	Mussels	Riparian Resources	Health & Safety	Recreation	Air	Transportation & Traffic	Cultural Resources	Socioeconomics
Hazardous waste sites		-	-		-	-				
Natural Climatic Events										
floods		+		+	-	-		-		-
droughts		+			-	-		-		-
severe storms		+			-	-			-	-
earthquakes					-				-	
Regulatory Environment										
Phase I & 2 NPDES program	+	+	+		+					+
TMDLs	+	+	+		+					
Site remediation		+	H/M +		+					
More stringent quality standards for environmental media	+	+	+		+	+	+			
Pollutant source control	+		+		+		+			
Wetland mitigation banking		+				+			-	
Carbon sequestration		+	+		+					
Farmland preservation		+	+			+				
Effluent trading	+				+					
Control of agricultural discharges	+		+		-	+				
Pollution Prevention			+							
Emissions trading					+		+			
COE permitting programs		+						-		H/M+
Small navigation projects		-	-	-	-	-				
Boating safety regulations					+	+				
ORSANCO monitoring program	+	+	+		+	+		+		+
Spill response	+	+	+		+	+				+
Information and FOIA										
Environmental Awareness Education	+		+	+	+					
ESA (Endangered Species Act)		+	+							
Environmental sustainability practices		+	+	+	+	+				

Key to shading/symbols:

Indicates high importance ranking
Indicates high-medium ranking H/M
Indicates medium importance ranking
Effect on resource is primarily positive +
Effect on resource is primarily negative -
No symbol for mixed + and - impacts

No shading indicates the RFFA is of low importance ranking or was not ranked.

Table 2-5 lists the indicators developed for the six higher priority VECs. Indicators were selected independently for each VEC, but they frequently overlapped between or among allied VECs. For example, indicators for water & sediment quality, fish, mussels and riparian/floodplain resources have similarities related to potential pollution, habitat

alterations, and biodiversity. These similarities underscore the intricacies and interdependence of environmental resources and the importance of assessing resources cumulatively in large systems such as the Ohio River.

TABLE 2-5
Indicators of Environmental Sustainability by VEC

Indicators for Water & Sediment Quality

- measures of key water quality parameters, including dissolved oxygen, pH, fecal coliforms, turbidity, total suspended solids and nutrients
- level of conformance with state and federal water quality standards, including attainment of permissible use designations
- TMDL (total maximum daily load) implementation
- effectiveness of specific point source control and nonpoint source control programs
- ability to sustain diverse, healthy populations of aquatic organisms, and
- effectiveness of spill response, monitoring programs and related precautionary measures

Indicators for Fish

- composition of fish communities, including numbers of intolerant and nonnative species, abundance and diversity
- amount of habitat with stable substrates, adequate depths, suitable currents, and sufficient food supplies
- reproductive viability as measured by amount of spawning habitat, genetic connectivity, and numbers of gravid females and larval individuals
- percent of population with abnormalities such as parasites, tumors, ulcers, and fin erosion
- water quality measurements such as levels of dissolved oxygen, and pH and
- level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic

Indicators for Mussels

- amount of habitat with stable substrates, suitable depths, and currents and connectivity to other mussel populations
- measures of water quality parameters important to mussel populations
- extent of food supplies to help ensure good growth rates and reproduction
- availability of fish hosts to ensure reproductive success and maintain species diversity
- extent of disturbance from biotic stressors, such as invasive Asian clams and zebra mussels and from abiotic stressors, such as river traffic

Indicators for Riparian/Floodplain Resources

- adequacy of hydrologic connections between riparian areas and adjacent water bodies and uplands
- capacity for water storage in floodplain
- quality of soil structures
- adequacy of water table and groundwater recharge
- sustainability of sediment dynamics
- capacity of riparian areas to intercept pollution
- integrity of riparian habitats and
- measures of biodiversity

Indicators for Health & Safety

- number and magnitude of spills of oil, fuel, and other hazardous or toxic materials
- potential sources of contamination associated with past or present activities
- number of accidents associated with commercial or recreational boating

- number and types of public advisories related to boating, swimming and fish consumption
- noise levels from construction activity, commercial transportation and other sources

Indicators for Recreation

- types of recreation and associated opportunities
- availability of recreational-related facilities (e.g. boat launch ramps, marinas)
- quality of experience related to river conditions (e.g. density of watercraft, safety concerns)
- number and types of public advisories related to boating, swimming and fish consumption

2.8 APPROACH TO ANALYZING ENVIRONMENTAL SUSTAINABILITY

The ES categories of the various VECs included in the CEA were derived by combining the best professional judgment of the Central Planning Team and IWG members with the CEs of multiple actions (i.e., RFFAs) as manifested through information available on indicators selected for each VEC. Although ES categories are somewhat qualitative, they are based on thorough analyses of past and present conditions as well as future conditions related to trends, plans, laws, regulatory programs and other sources of information that are beyond mere speculation.

Categories of ES were determined for the past, present and future of each VEC. Specific ES categories were developed for each VEC and are found in the corresponding CEA chapters. The general template for the ES categories follows:

- Not sustainable (NS) – The composite conditions of the selected indicators do not reflect conditions that can sustain the resource long-term.

- Marginally sustainable (MS) – The composite conditions for the selected indicators are such that the resource can be sustained for the majority of river miles in or along the Ohio mainstem, but conditions of the indicators are somewhat tenuous both in location and likelihood of occurrence.

- Sustainable (S) – The composite conditions of the selected indicators reflect sustainability for essentially all the river miles in or along the Ohio mainstem. Further, conditions of the indicators meet or exceed regulatory thresholds and pertinent governmental programs are in place to support the resource.

2.9 ES CONCLUSIONS BY VEC

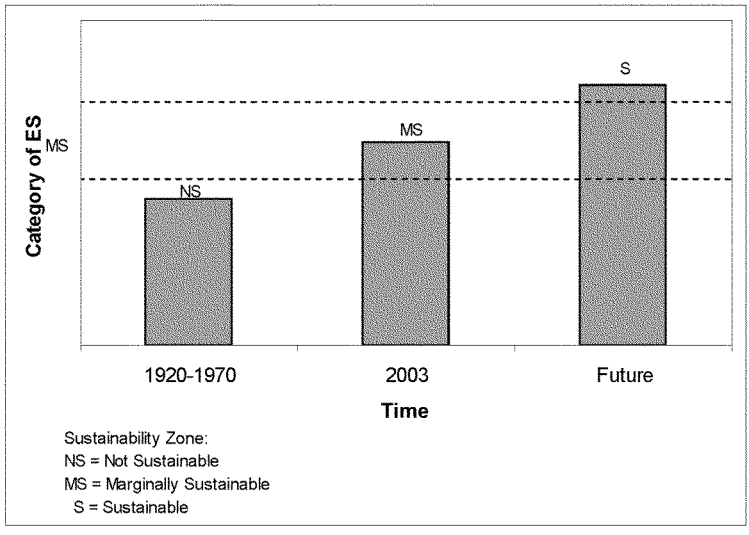
Applying this methodology to each VEC in the CEA resulted in past, present, and future characterizations of ES that were included in bar graphs accompanied by synopses of conditions. Because of implementation of important legislation or the quality of information available, more than one ES category may be used to categorize past conditions.

The following sections present the ES graphs (**Figures 2-1 through 2-11)** and their respective synopses which form the basis for additional conclusions related to interactions among VECs, overall CEs, and sustainability of the Ohio River mainstem.

Water Quality and Sediment Quality

Prior to 1920, and continuing up to about 1970, the water quality of the mainstem was in a degraded state characterized by low DO concentrations, low pH levels in the upper river, high bacterial contamination, high nitrogen concentrations, and remobilization of potentially toxic chemicals that had become associated with river sediments. Essentially no pollution reduction programs, control programs, or regulatory programs were in place during this period. Further, declines in the diversity and health of fish communities in the mainstem had occurred. Accordingly, the ES of water quality was classified as "not sustainable". Primary contributors to these conditions were the largely untreated and uncontrolled point and nonpoint pollutant discharges from growing municipalities and various types of industries and land uses along the river.

FIGURE 2-1
ES of Water Quality



Due to the programs of ORSANCO, and requirements of the Federal Water Pollution Control Act (FWPCA) (and the amended Clean Water Act (CWA)), water quality of the Ohio River has shown steady improvement in recent decades. For example, Dissolved Oxygen (DO) concentrations are typically above the 5.0 mg/L standard, pH levels are between the 6.0 to 9.0 standard, and nitrogen concentrations meet current water quality criteria. However, continuing concerns include bacterial contamination primarily associated with NPS pollution downstream from major urban areas, legacy "contaminated sediments" in the upper river, and fish consumption advisories throughout the mainstem. In contrast, the results of algae (plankton) and aquatic macroinvertebrate surveys in recent decades have demonstrated steady improvements in these resources, which parallel water

quality improvements. Regarding the attainment of permissible use designations, as of 2003, 779 of 981 miles (~80%) of the mainstem were "fully supporting" aquatic life, and 949 miles (~97%) were "fully supporting" public water supply use. None of the mainstem was "fully supporting" fish consumption due to consumption advisories along its total length. For contact recreation, 269 miles (~27%) were "fully supporting", with major impairment continuing from combined sewer systems in urban areas. Overall, implementation of NPDES permit programs for municipalities, industries, and stormwater has led to the reduction of discharges into the mainstem. Initiatives for increasing the use of Best Management Practices (BMPs) have also been established. Further, the diversity and health of fish communities along the mainstem has considerably improved. Accordingly, as of 2004, although there are many positive signs, the ES of the water quality VEC is classified as "marginally sustainable".

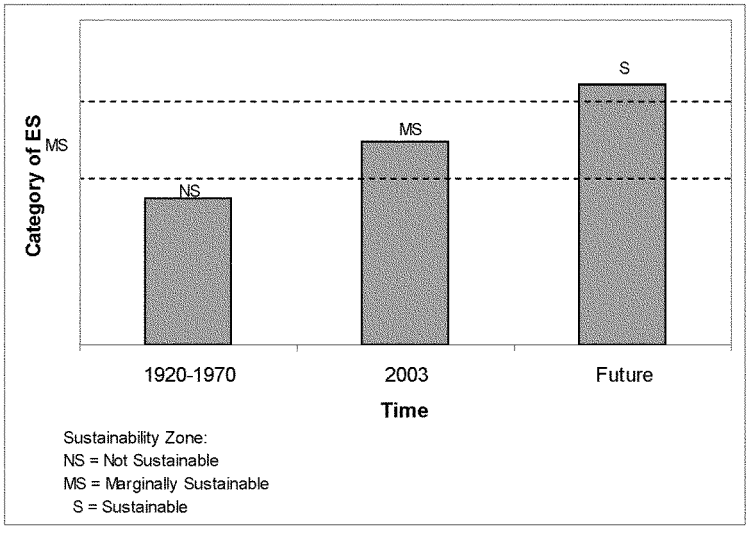
Regarding the future, it is expected that water quality of the Ohio River mainstem will further improve with continuation of source control and other pollution reduction programs, and other remediation efforts. Therefore, it is anticipated that the ES of water quality will achieve a "sustainable" condition. However, vigilant efforts are still needed to continue effective water quality and aquatic ecological monitoring and management efforts. In this regard, it may be desirable to plan and implement source monitoring programs for selected RFFAs (actions) considered of high importance relative to cumulative effects. Further, special surveys for legacy-contaminated sediments are needed along with site-targeted efforts to reduce bacterial pollution from CSOs. Actions expected to be beneficial to water quality in the future include implementation of nonstructural navigation improvements and technological improvements related to communications and more environmentally-advanced barge design. Activities that support commercial navigation (e.g., port development and maintenance dredging) will continue to be scrutinized by regulatory agencies and nongovernmental organizations (NGOs) and may be more strictly regulated. Some redevelopment activity may revive underused urban space or industrial brownfields areas, with possible long-term water quality benefits related to clean up. Much development activity, however, will involve conversion of existing floodplain lands that now afford habitat protection, open space and ecosystems values. Once converted, such lands are unlikely to revert to their former more natural states. Increasing emphasis on pollution prevention, erosion control BMPs, and implementation of the Phase 1 and 2 NPDES programs could counteract some adverse impacts, particularly in more urban areas. In general, several regulatory initiatives in recent years should measurably improve water and sediment quality, but it is not possible to predict the magnitudes of their beneficial effects.

Fish

Prior to1920 and continuing well into the mid-20th century, fish communities became degraded, as reflected in the decline of many native species and the increase in pollution tolerant species. This decline was particularly pronounced in the upper and middle river, where human populations grew rapidly during the first half of the 20th century, concurrent with increased inputs of domestic sewage, industrial effluent, and acid mine drainage. Numerous other actions contributed to degradation of fish communities, including land clearing and sedimentation beginning in the 19th century, impoundment of the river by navigation dams that disrupted migrations of several important river fishes, in-stream sand and gravel dredging, development of new ports, terminals and marinas, introduction of the

common carp, and increasing quantities of stormwater runoff from urbanizing areas. Because these actions contributed to habitat loss, changes in species composition and abundances, and serious declines in necessary water quality conditions, the ES for this period is classified as "not sustainable". Further, until 1948, when a limited precursor of the CWA was passed and the ORSANCO interstate compact was signed, pertinent laws were limited. Accordingly, based on scientific data indicating changes in fish communities as well as the recognition of multiple actions and factors causing such changes, it was concluded that the composite conditions for the selected indicators of ES for fish communities did not reflect conditions that would sustain diverse, healthy fish populations throughout the river.

FIGURE 2-2
ES of Fish Communities



From the mid-20th century until the present time, improvements in the sustainability of the fish resource have been observed throughout the mainstem. Such improvements have resulted primarily from initiatives by ORSANCO, efforts of the six Ohio River states, and the requirements of the FWPCA and the amended CWA. As municipal wastewater and industrial effluents to the river have decreased and other pollution control measures have increased pH and DO while reducing toxins, fish communities of the Ohio River have shown steady improvement, marked by the recovery of many native species. The common carp is no longer as dominant as in earlier years. Concurrent with improvements in water quality, however, has been the continued inundation of fish habitat not only from navigation structures constructed before 1950, but also from continuing construction and operation of additional high-lift dams. The modern navigation system, combined with land use and flood control practices in the watershed, has caused the inundation and siltation of extensive areas of gravel substrates preferred by many migratory fishes. Various studies on human impacts on Ohio River fishes, including studies on winter habitat and fish passage, underscore the need for additional research and development of resource management practices to gain a more comprehensive understanding of ES of mainstem

fish. Accordingly, the ES of the fish resource at present is classified as "marginally sustainable." Two major uncertainties emerged during the last decade that may affect the fish resource into the future: 1) the invasion of four Asian carp species and 2) the invasion and unknown population dynamics of zebra mussels, which seriously impact native mussels, an important food resource for many fish species.

Regarding the long-term future, the CEA has identified 60 RFFAs ranked as having high or medium importance. These include actions that change habitat, change disturbance regimes, change hydrological patterns, affect ecological functions, and are related to population changes. During recent decades, regulatory requirements and pollution control programs have been implemented that will benefit the fish resource, if continued into the future. Additional tools and studies that also should increase understanding of the ES of fish in the mainstem include the NAVPAT habitat assessment model, the new Ohio River Fish Index (ORFIn), and supplemental fish studies related to §316(a & b) of the CWA. It is also expected that the Ohio River Fish Management Team and USFWS Ohio River Valley Environmental Team will continue to be involved in fish resource monitoring and management. Given recent improvements in the resource, development of new assessment tools, and the level of stakeholder interest, it is expected that fish communities of the Ohio River mainstem will attain a "sustainable" condition and may further improve with long-term elimination of combined sewer overflows and better nonpoint pollution control. The habitat effects of impoundment of the river are expected to persist into the future, but adaptive management may produce measures that counteract such effects and benefit habitat and enhance interpool connectivity. A possible threat to the resource is the invasion of Asian carps. Vigilance by ORSANCO and other resource agencies will be required to assess populations of Asian carps while potential measures to control these species are evaluated for the Ohio and other major river systems in the U.S.

Mussels

To summarize the historical and current status of mussel populations in the Ohio River mainstem, the following observations can be made:

- Over the last century the number of mussel species has declined from about 80 to the currently reported 54 species. Evidence suggests that the number reached a low in the vicinity of about 25 to 35 species in the 1950s and 1960s. Numerous factors contributed to the decline, including, but not limited to, water pollution from municipalities, industries, and acid mine drainage; instream extractions of sand and gravel; construction and operation of high-lift locks and dams; and disruptions to mussel beds due to barge fleeting areas, queuing, and disposal of dredged materials. Recent increases in the numbers of species can be attributed to water quality improvements and protection efforts related to mussel beds. However, despite these advances, research continues on the unique characteristics of the life cycles of numerous mussel species, and their susceptibility or resiliency regarding natural stresses from dynamic river flows and water quality, and from human-induced stresses associated with economic development activities. The greatest factor affecting mussels in the mainstem Ohio River is habitat alteration resulting from impoundment by the high lift dams.

- The lower portion of the river was not as severely affected by water quality degradation as the upper river. As a result, the lower river typically had and continues to support more diverse mussel populations and generally higher densities than the upper river. However, concerns currently exist relative to fluctuating populations of invasive zebra mussels and potential appearance of black carp. Thus there is a need for additional research on the interactive relationships between the invasive species and native mussels and their associated life cycle, including fish hosts.

- Five mussel species (fanshell, pink mucket, orangefoot pimpleback, clubshell, and fat pocketbook) are currently Federally listed as endangered for the mainstem, and recovery plans have been developed for each. Candidate species include the sheepnose mussel, rayed bean, and spectacle case; the latter species has not been found recently in the Ohio mainstem.

- As more information is assembled on the locations and characteristics of mussel beds in the mainstem, planning and implementation of targeted and long-term mussel monitoring programs can be more effectively accomplished. Further, the results can be used in an adaptive management program focused on enhancing and maintaining the ES of the mussel resource.

Based upon the above-described affected environment conditions, the consideration of multiple actions and their effects, the discussion of the connections with the three tiers of indicators, and the ES categories, the ES of mussels of the mainstem of the Ohio River can be characterized and depicted as follows:

In the time period from 1920, and continuing up to the mid-point of the last half of the 20th century, the ES of freshwater mussels in the mainstem was in a continuing decline and thus classified as "not sustainable". The decline in mussel species and densities, and the areal extent of mussel beds, was particularly noted in the upper and middle river segments, with the lower river experiencing a similar, but lesser decline. Numerous actions contributed to the decline, including, but not limited to, acid mine drainage in the upper river, high-lift locks and dams disrupting mussel and fish-host migration, numerous discharges of untreated to partially treated municipal and industrial wastewaters, in-stream sand and gravel mining, dredging for new ports and terminals, periodic maintenance dredging for the navigation system, mussel harvesting for button manufacturing and the cultured pearl industry, and multiple land use changes resulting in increased nonpoint source pollution. These actions and others contributed to losses in quality mussel habitat throughout the river, declines in necessary water quality conditions, and disruptions in various components of the mussel life cycle. The greatest factor continuing to affect mussel resources in the Ohio River is presence of high-lift dams with attendant modification of clean-swept gravel, cobble, and sand substrates now covered and/or replaced by finer-grained material. Additional contributing factors to this decline included the limited information on life cycle requirements of several mussel species and poor understanding of the influence of biological and physical-chemical conditions on timing reproduction. Further, there was limited recognition of the biological importance of mussels, and limited existence of environmental and resource protection laws up to 1948 (FWPCA) and 1973 (when the ESA was passed). Accordingly, as a result of the scientific data indicating declines in various mussel populations in the mainstem, as well as the

recognition of multiple actions and factors causing such declines, it was concluded that the composite conditions for the selected indicators of ES for mussels did not reflect conditions that would sustain diverse, healthy populations of freshwater mussels throughout the river.

In the time period from 1975 up to 2003, some improvements in sustainability of the mussel resource in the mainstem have been noted, although improvements are typically localized and exhibit frequent fluctuations. Conversely, there has also been a general reduction in number of mussel beds since about 1975. Improvements that have occurred resulted from: 1) reduced acid mine drainage in the upper river, 2) enhanced treatment requirements for municipal and industrial wastewater treatment plant discharges, 3) consideration of mussel bed locations in river-related permitting programs (e.g., Section 404 and Section 10 permits) and navigation system operational features (location of queuing and barge fleeting/storage areas, and placement of dredged material), and 4) protection provided through designation of several mussel species as threatened or endangered under the ESA and similar state protective mechanisms.

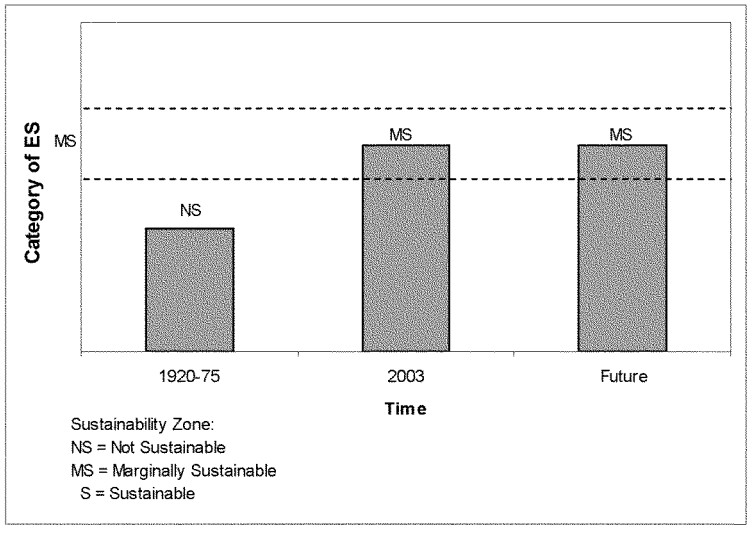
Recent fish migration research indicates evidence of some inter-pool movement (see Chapter 4, FISH); however, it is not clear if sufficient host fish are able to move successfully from a mussel assemblage in one pool to suitable mussel habitat in another pool, especially when carrying mussel glochidia. The designation of "marginally sustainable" is appropriate considering that composite conditions for the selected Ecological Sustainability indicators are such that diverse mussel populations are occurring only along some segments and in some pools of the river and that conditions of the indicators are somewhat tenuous both in location and likelihood of occurrence. The conditions also reflect a continuing level of uncertainty regarding appropriate quantitative measures of the Ecological Sustainability of freshwater mussels.

Six previously designated endangered species have not been recently found in the mainstem; however, five others are continuing in the river due, in part, to natural recovery. In contrast to the improvements, concerns still exist regarding the occurrence of nonindigenous species such as zebra mussels and possible future establishment of black carp. The most recent decade has been characterized by expanding databases to include results of scientific studies of freshwater mussels in the Ohio River. These databases, although incomplete, have been used in recent environmental planning and permit programs and are providing the bases for on-going research efforts into the life cycle of various mussel species. As a result of relatively recent scientific data (since 1990) indicating recruitment and general improvement in some mussel populations in navigation pools in the lower, middle, and some upper portions of the river; the recognition of improvements in water quality and general habitat conditions resulting from various features of the CWA and ESA, and evidence of inter-pool movement, albeit somewhat limited (see Chapter 4), it is concluded that the current ES classification is "marginally sustainable,"

Regarding the future, this study has identified 56 types of RFFAs ranked as having high importance relative to CEs on native mussels, and 14 additional types ranked as having medium importance. These 70 RFFAs include actions that directly or indirectly contribute to mussel habitat degradation and instability, affect reproductive success and community connectivity, or are beneficial to mussels (numerous regulatory and

educational actions are included in this latter group). As additional regulatory requirements and pollution control programs are implemented, habitat conditions should be more conducive to reproductive success and community connectivity than at present. Of particular importance is the need to integrate considerations of mussel beds and the life cycle features of mussels into permitting and other locational decisions within or along the mainstem. As further mussel monitoring and research is conducted, these data should be added to databases to provide further information for both protecting and promoting mussels. Further, consideration should be given to implementation of an integrated adaptive management program for the Ohio River freshwater mussels.

FIGURE 2-3
ES of Mussel Resources



This assessment of future marginal sustainability acknowledges that many unknowns remain and that recovery of the Ohio River mainstem native mussel populations will be a long-term process involving many years of collaborative efforts and monitoring. Evidence of recruitment and population stability is necessary to validate viability. To illustrate the many uncertainties, the following tasks to effect recovery have been selected from a more extensive list from Watters (1994) and supplemented by the ORMSS IWG:

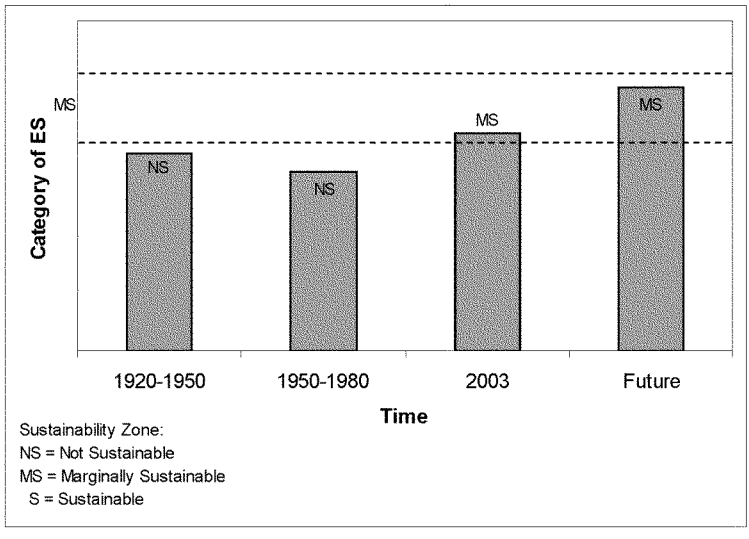
- Identify other resource values associated with mussel populations, including fish hosts, key food organisms, and habitat elements.
- Protect and manage mussel populations and their habitat on a site-specific basis to avoid future net loss of available habitat or populations.
- Characterize the habitat that best supports species of concern, including historically important sites.
- Restore habitats and reintroduce mussel species to suitable areas.
- Conduct searches for additional populations.

- Enforce all laws and regulations pertaining to collection of specimens and protection of habitat.
- Enhance knowledge of life histories for species of concern, including life histories of host fishes.
- Identify the potential effects and responses to zebra mussel and Asian carp species invasions and their control measures.
- Evaluate the efficacy of removing zebra mussels from vessels to prevent re-infesting areas.
- Increase public and agency awareness of existing laws that protect mussels.
- Use media opportunities to reach the general public and encourage involvement in the recovery process.
- Restore and protect direct connections to tributary populations.
- Restore mobility of fish hosts through dams at appropriate times of the year needed for mussel reproduction.

Riparian/Floodplain Resources

In the time period prior to 1920, and continuing up to about 1950, the riparian/floodplain resource (RFR) can be classified as "not sustainable" due to relatively rapid losses of riparian habitats and their functions, the lack of knowledge of the importance of these resources to both terrestrial and aquatic ecosystems, and the essential absence of any institutional programs to manage or control riparian areas. Further, the lack of awareness of environmental services performed by RFR coupled with ongoing floodplain development, especially in the upper and middle river, led to loss and fragmentation of valuable RFR along the Ohio mainstem before such resources could be well-documented.

FIGURE 2-4
ES of Riparian/Floodplain Resources



In the time period from 1950 to 2000, worsened "not sustainable" conditions occurred in the first several decades as a result of still more disruptions and losses of riparian areas. However, recent decades have included an increasing awareness of riparian services, including regulation of wetlands, a highly productive riparian component. The establishment of the Ohio River Islands National Wildlife Refuge has focused attention on the disappearance of another riparian habitat type, islands, and has heightened visibility of the riparian resources of the Ohio mainstem embayments. These initiatives suggest the current status of RFR may be moving toward "marginally sustainable." Accompanying these initiatives is an increasing recognition that institutional programs must be established to protect RFR.

Regarding the future, the growing awareness of environmental services performed by RFR, as well as increasing demand for river corridor enhancement and protection for passive recreation may help move RFR toward a more sustainable future. However, it is less certain if environmental regulations and institutional programs will be in place to support RFR sustainability and stem fragmentation and loss of RFR from development along the Ohio River mainstem. Accordingly, the future ES of RFR is classified as "marginally sustainable."

An important issue is the need for institutional programs for riparian area management. Examples of such program features include, but are not limited to:

- requiring impact identification and mitigation via NEPA,
- designation of special management areas on public lands,
- regulation of activities on privately-owned riparian areas,
- utilization of incentives such as cost-sharing, low-cost loans, or tax reductions to encourage the use of BMPs on riparian areas, and
- the purchase of privately owned riparian lands, either in fee or by easement, for public management.

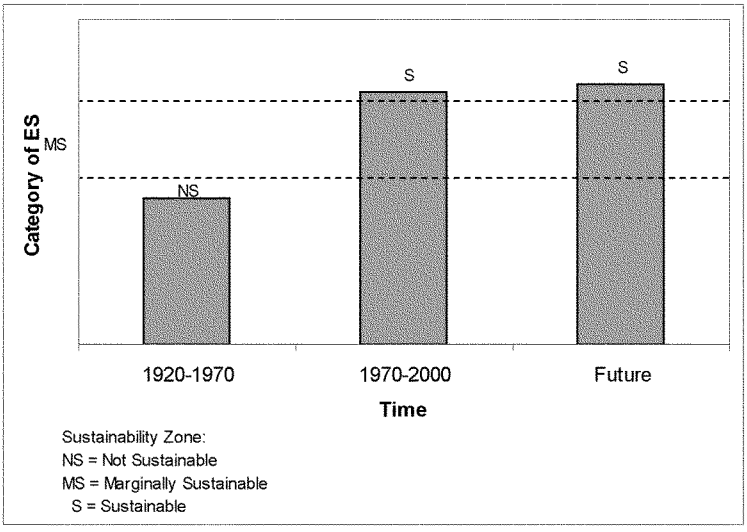
Air Quality

In the time period prior to 1920, and continuing up to about 1970, the air quality of the Ohio River Valley was in a degraded state and thus classified as "not sustainable" due to largely untreated and uncontrolled point and nonpoint pollutant discharges from coal fired power plants, other types of industries and vehicular sources.

Due to the requirements of the Federal Clean Air Act of 1970 (CAA) and subsequent amendments, the air quality in the region has shown a steady improvement in recent decades; thus it is currently in a "sustainable" category.

Regarding the future, it is expected that air quality in the Ohio River Valley will further improve as a result of the continuation of source control and other pollution reduction programs; therefore, it will be maintained in a "sustainable" condition. However, this characterization should not bring complacency; rather, vigilant efforts are still needed to continue effective air quality monitoring and management efforts. Such efforts are reflected in the recent implementation of more stringent standards for ozone and particulate matter and ongoing efforts to establish effective limits for mercury and to continue analysis of the need to control other types of emissions.

Figure 2-5
ES of Air Quality



Health and Safety

In the time period prior to 1920 and continuing into the 1960-70s, health and safety (H&S) issues on the Ohio River represented a broad spectrum of risk factors. Construction and workplace conditions were generally more dangerous than at present; spills and discharges from commercial navigation, river oriented industries, and untreated municipal effluents contributed to a variety of public health risks; and little or no information was available to advise the public of ambient risk levels associated with river oriented activity.

While individual risk factors no doubt varied significantly from time to time, most H&S related issues for the period are categorized in **Figure 2-6** as 'marginally sustainable.' However, activities that involved more direct exposure to water quality risk factors are categorized as 'not sustainable' in **Figure 2-7**.

Improvements to water quality, reduced risks of spills and faster response, improved workplace safety standards, and effective safety standards for recreational boating have all combined to make the Ohio River a safer place to work, live, and play. These improved present day conditions result in a 'sustainable' classification in **Figure 2-6.** Improved conditions have also contributed to reduced risk factors associated with contact recreation and fish consumption. However, problems associated with continued exceedances of biological standards, the persistence of some contaminants associated with fish consumption, and mixed signals regarding fish consumption standards result in a present time classification of 'marginally sustainable' for these activities.

FIGURE 2-6
Health & Safety for Workplace and Boating Accidents

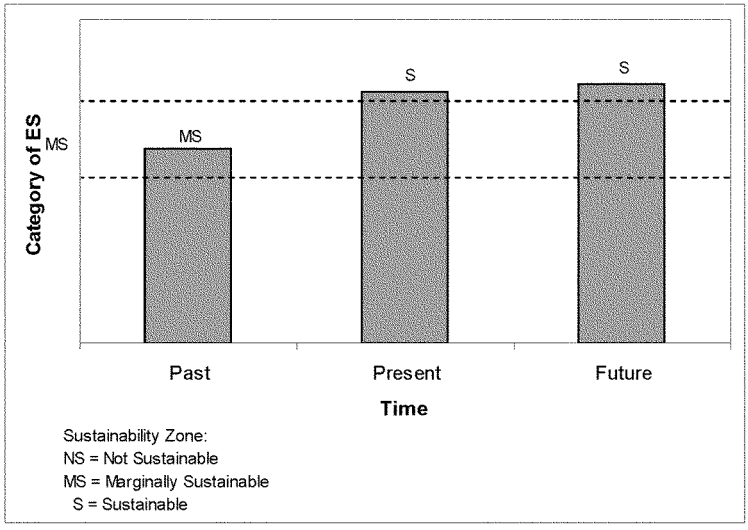
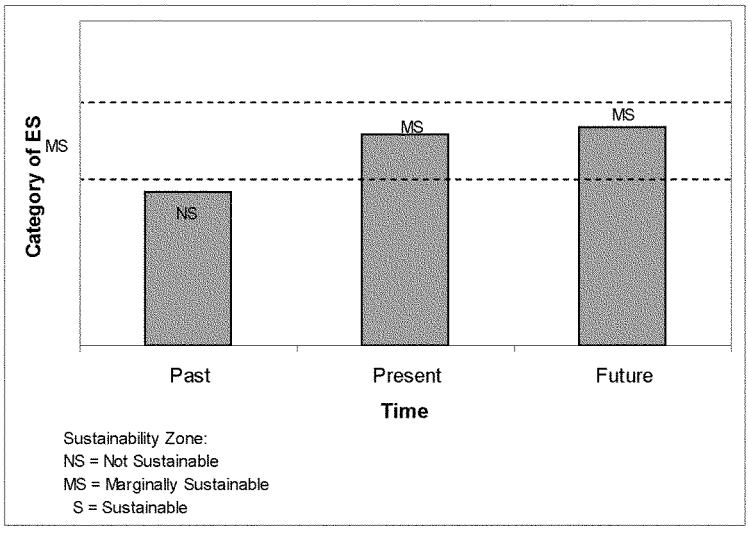


FIGURE 2-7
Health & Safety for Contact Recreation and Fish Consumption



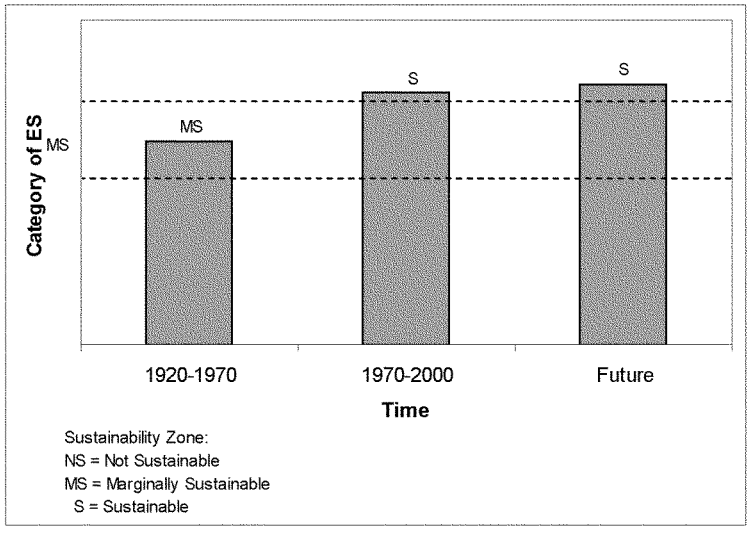
With respect to the future, most H&S issues are expected to remain in the 'sustainable' rankings. It is important to note, however, that continued growth of commercial navigation, recreational activity, river oriented industries, and other uses of the river will require continued improvements in management and regulation of H&S issues just to maintain the status quo.

While improvement of risk factors associated with contact recreation and fish consumption is expected to continue, these factors are kept in the 'marginally sustainable' category as a conservative estimate of potential trends. Some efforts required for continued improvement, such as rehabilitation of sanitary sewer systems to eliminate CSOs and SSOs or reduction of mercury emissions from coal combustion, will require significant investments and long periods of time to achieve results.

Recreation

• In the time period prior to 1920, and continuing up to about 1950, recreation on the Ohio River occurred in a degraded environment due to largely untreated and uncontrolled pollution discharges from growing municipalities, mining activity, and various types of industries and land uses along the river. Although the river continued to be used for recreation during this period, the overall ES was "marginally sustainable" and may have been "not sustainable" for the worst years of pollution. However, recreation information from the worst decades of pollution is limited as that time period coincided with the Great Depression, World War II, and the post-war period shortly thereafter, when leisure time and financial resources were limited.

Figure 2-8
ES of Recreational Resources



• At the present time, recreation on the Ohio River is currently in a "sustainable" condition due in large measure to water quality improvements related to ORSANCO programs and requirements of the FWPCA (and the amended CWA). Water quality improvements, combined with increased economic prosperity, have increased the demand for and stimulated the development of marinas, ramps and other recreation facilities along the river. The recent era of more integrated riverfront planning also has addressed

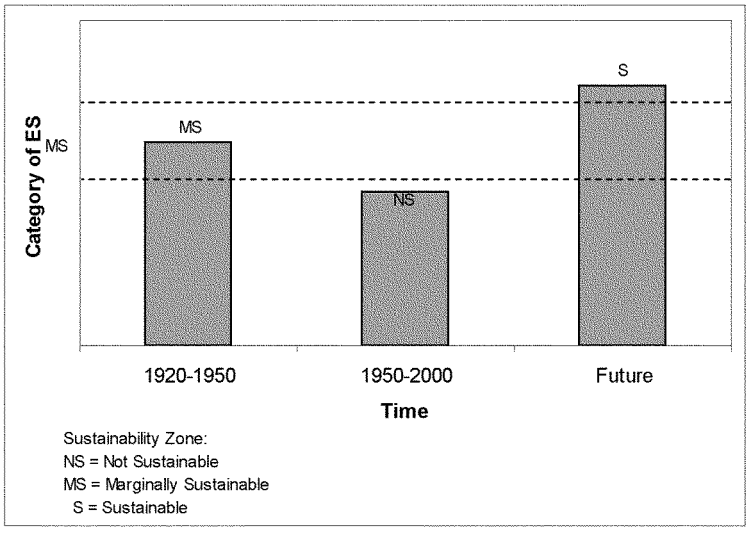
recreation needs and has increased opportunities for an expanded spectrum of recreational choices.

- Regarding the future, it is expected that community planning and development of recreation facilities, further water quality improvements, especially in stormwater and CSO management, and habitat protection and restoration efforts will continue to enhance recreation experiences. Socioeconomic projections for a stable or slowly growing population and continued improving standard of living would be expected to result in continued growth of demand for recreational opportunity. Consequently, the future ES is classified as "sustainable." Although the perception exists that increased participation could lead to overcrowding and competition for limited resources, it does not currently seem to be an overriding influence affecting people's decisions to participate in river-related activities.

Transportation and Traffic

In the time period prior to 1920, and continuing up to about 1950, the waterway transportation and traffic system can be classified as "marginally sustainable". This classification is a result of system capacities that tended to exceed demands; however, the system was not particularly cost-effective or efficient, nor was it focused on minimizing externalities.

FIGURE 2-9
ES of Transportation and Traffic System



In the time period from 1950 to 2000, "non-sustainable" conditions were often experienced as a result of the construction of new infrastructure, demands that exceeded system capacities at numerous locations, and the use of auxiliary locks during repair and maintenance periods. In fact, due to the aging infrastructure, it can be anticipated that the

"non-sustainable" conditions will continue into the future, and even further decline, in the absence of the system investment plan and its implementation.

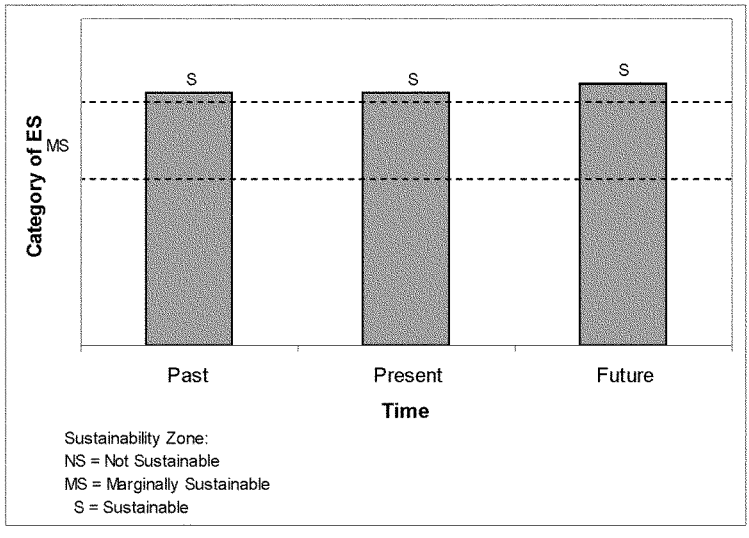
Regarding the future, it is anticipated that the sustainability of the transportation and traffic system will improve as a result of navigation investment actions. Even if recreational uses of the river markedly increases, there is adequate capacity to handle these boats when both chambers are operating.

Socioeconomic Resources

Historic, present and future trends for socioeconomic resources in the Ohio River study area illustrate a pattern of increasing sustainability, related to population growth and conversion of natural resources and landscapes.

The past was characterized by rapid conversion of natural resources and landscapes to meet the industry and infrastructure demands of a rapidly expanding population. Although socioeconomic resources were generally sustainable, volatile patterns of explosive growth and recession cycles occurred such that the ES was somewhat less stable than in recent decades.

Figure 2-10
ES of Socioeconomic Resources



At present, the region offers a reasonably healthy mix of agriculture, varied industries, and commercial, financial, education, and health care services and is supported by a fully developed economic infrastructure. This economic infrastructure includes rail, highway, river and air transportation, modern communication capabilities, and affordable and reliable utilities, including coal fired electricity generation that depends directly on the river navigation system. The social system is equally well established, with a generally

healthy, educated and technically skilled population supported by an established network of urban, suburban, and rural communities.

In recent decades, improved water quality has contributed to increased redevelopment interest for many riverfront neighborhoods. Growing interest in environmental amenities within residential/commercial settings contributes to the design of community oriented restoration projects that combine floodplain functionality, aquatic and riparian habitat enhancement, open space, recreational activities, stormwater detention, and related functions within multi-purpose or integrated aquatic restoration projects.

Regarding the future, the projected slow population growth and attendant slow growth of the economy allows for a gradual expansion from the existing infrastructure and an opportunity for relative economic stability in contrast to the 'boom and bust' patterns of the past century. The projected growth patterns may present opportunities to proceed with gradual and better planned processes of development and redevelopment serving the needs and interests of a stable and established population. This steady pattern for development should score higher for sustainability than the more volatile pattern of the past.

Further, ongoing investments in social and economic infrastructure should have a generally positive impact on Socioeconomic Resource values. For the Ohio River valley, most primary infrastructure investments have already been accomplished, including a complete system of interstate and other primary highway networks, railroads, river bridges, airports, locks and dams, levees and floodwalls. Expansion plans for infrastructure continue on the basis of projected demand or existing capacity expansion needs, but a relatively stable population for the foreseeable future should contribute to reduced growth rate in demand for additional primary infrastructure. Future improvements to this system would focus primarily on maintenance, refinement, or replacement of the existing inventory.

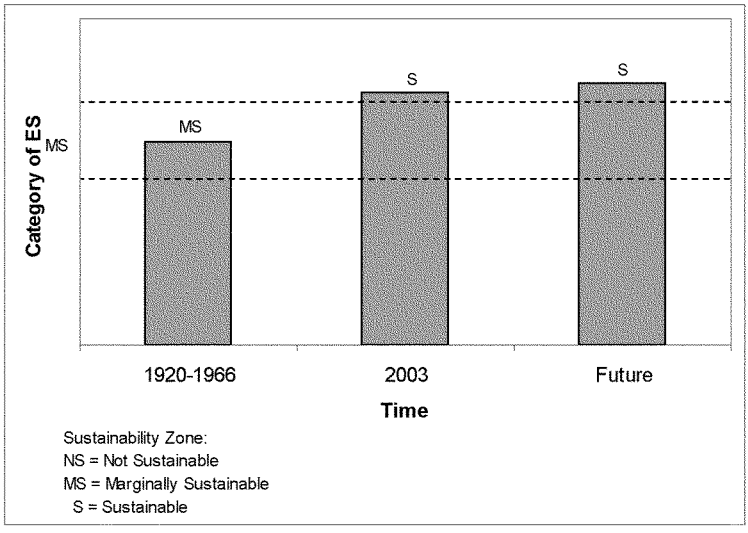
Both lock extension/replacement and ongoing maintenance/repair of existing locks would contribute to positive socioeconomics impacts. Within the context of the larger economy of the Ohio River valley, these actions would contribute fairly small, but cumulative impacts. Long term growth of navigation traffic will require more tugs and barges in operation, more terminals and related port facilities, more maintenance dredging for expanded terminals, and expanded areas of fleeting operations. These expansions would convert existing floodplain lands (e.g., farmland, riparian woods, and wetlands) that now afford habitat protection, open space, and ecosystems values to other uses. Once converted, such lands are unlikely to revert to their former more natural states. Expansion of navigation infrastructure would also compete for space with expansion of riverfront industries, coal fired utilities, mining and other commercial operations. Mixed-use urban waterfront developments, marinas, and other recreation-oriented developments would also compete for waterfront space. Waterfront development policies that support the conversion of brownfields, unused or underdeveloped terminals, or other underutilized industrial sites could help to minimize conversion impacts to existing agricultural uses or riparian habitats.

Cultural Resources

In the period from 1920 and continuing until passage of the National Historic Preservation Act of 1966 (NHPA) and other preservation acts later in the 20th century, limited measures were in place to preserve and protect cultural resources; most resources remained unsurveyed. Widespread razing of potentially historic structures during this time is viewed by some State Historic Preservation Offices (SHPO) professionals as having contributed to a decline such that cultural resources may overall have been at the "marginally sustainable" level.

The implementation of cultural resources legislation, including creation of the National Register of Historic Places and establishment of SHPOs, has heightened awareness of the need to preserve historic structures in communities along the Ohio River. Simultaneously, NHPA provisions that require consideration of cultural resources where federal involvement occurs have led to the discovery and preservation of previously unknown cultural resources. Accordingly, the ES classification for the current time is "sustainable."

Figure 2-11
ES of Cultural Resources



Regarding the future, federal and state regulations concerning cultural resources are expected to remain in place and help maintain a "sustainable" condition. During each year of this study, additional resources have become eligible for possible placement on the NRHP, although some SHPO professionals have observed that numbers of NRHP candidate properties may be limited due to societal trends toward disposability, tear down, and sprawl. Additional riverfront development, including recreational areas may result in covering or damage to cultural resources near the land surface.

Positive trends related to cultural resources include

- the development of predictive models to determine probability for cultural resources occurrences,
- recent emphasis on context integration of historic districts, and
- an increasing number of river festivals and other events through which residents of the Ohio River valley are rediscovering the rich cultural heritage of the river.

2.10 INTERACTIONS WITH OTHER VECS

CEA not only considers past, present, and future conditions and trends for individual VECs, but also the interactions which may occur among VECs. Assessment of VEC interactions is prescribed in Step 8 of the CEQ Guidelines: Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.

VEC interactions for the Ohio River mainstem were visualized by constructing a crosswalk of all potential interactions which were then ranked as high, medium, or low/no interactions, as shown in **Table 2-6.** Interactions rankings were based on information presented in individual VEC chapters of the CEA, as well as on best professional judgment of the project team members.

TABLE 2-6
Interactions among VECS in the ORMSS CEA

VEC Interactions*	WQ & SQ	Fish	Mussels	Riparian/Floodplain Resources	Air	Health & Safety	Recreation	Transportation	Socioeconomics
Cultural Resources				M	M		H	H	H
Socioeconomics	H	M	M	M	H	H	H	H	
Transportation	M	M	H	M	H	H	H		
Recreation	H	H	M	H	M	H			
Health & Safety	H	M			H				
Air	M			M					
Riparian/Floodplain Resources	H	H	M						
Mussels	H	H							
Fish	H								

*Key to shading:

High

Medium	
Low or no interaction	

2.11 ES OVERVIEW OF ALL VECS

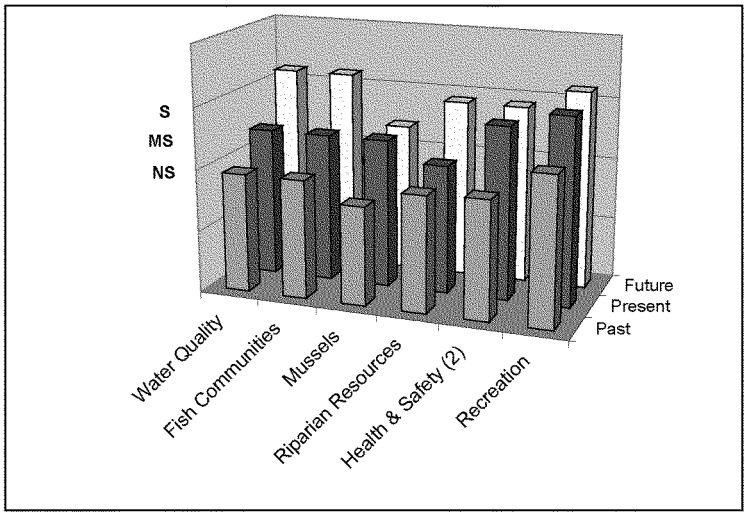
Of 45 VEC interactions cross-referenced in the table, 23 display a high level of interaction, 14 display medium interaction, and 8 potential interactions either have no or low interaction. The four VECS with the highest interaction levels are water & sediment quality (6 Hs), recreation (7 Hs), transportation (6 Hs), and socioeconomics (6 Hs). Other important VECs have fewer interactions in part because they are confined to only one environmental medium. Fish and mussels, for example, are confined to water and, accordingly, have very limited interaction with VECs such as air and cultural resources.

Combining ES classifications for individual VECs with interactions among VECs reveals an overview for all ten VECS discussed in the ORMSS CEA. In this context, ES values of certain VECs become important "drivers" that influence ES values of other VECs in the overall system. Most notably, dramatic improvements in ES of the Water Quality VEC, subsequent to implementation of ORSANCO programs and the Clean Water Act, have driven other components of the aquatic ecosystem of the Ohio River toward increased ES. The ES of fish has measurably improved, while ES of riparian resources and mussels have benefited to a lesser extent. Cleaner water and improved aquatic resources in turn have enhanced recreational boating and fishing on the mainstem and stimulated growth of related support facilities such as marinas. Cleaner water nationwide also has contributed to a trend toward increased development and use of trails, greenways and other recreational facilities along rivers, including the Ohio mainstem. Such recreation facilities often stimulate riverfront development, including restaurants and entertainment districts, which add to local economic growth, but concomitantly contribute to loss of riparian/floodplain resources and cultural resources.

H&S represents a VEC with improved ES in recent decades (due to improved water quality and more stringent workplace regulations), but with the potential for its ES to be driven downward by complex interactions with other VECs. Possible growth of commercial navigation, recreational activity, river-oriented industries, and other river users will require vigilance in management and regulation of H&S issues just to maintain the status quo.

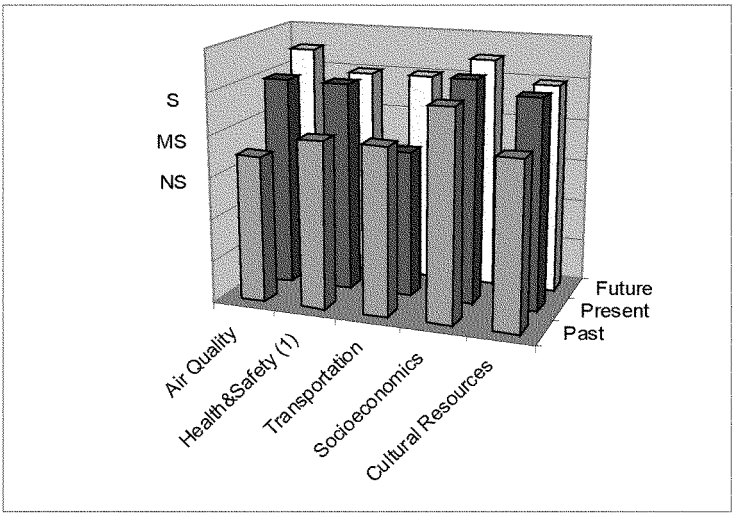
ES values of RFR and mussels are particularly confounding in part because of somewhat limited knowledge of these VECs. Regarding RFR, lack of knowledge until recently was correlated with the relatively low value assigned to these resources. Although interest in RFR has increased, these resources present a challenging complex of biogeochemical, hydrological and ecological processes. Similarly, Ohio River mussels are challenging to study, despite the fact that information on Ohio River mussels has been collected since the 1800s. Scientists studying mussels are hampered not only by lack of knowledge of reproductive cycles and habitats needs, but also by increased water depths due to impoundment of the river. The relatively precarious ES values for RFR and mussels are emphasized in the concerns and opportunities presented in the following section. **Figures 2-12 and 2-13** depict past, present, and future ES levels for all VECs.

FIGURE 2-12
ES Trends for VEC Group 1



Sustainability Scale: NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range

FIGURE 2-13
ES Trends for VEC Group 2



Sustainability Scale: NS, values in the "not sustainable" range; MS, values in the "marginally sustainable" range; S, values in the "sustainable" range

2.12 CONCERNS AND OPPORTUNITIES RELATED TO ES OF VECS

The conclusions section on ES of each VEC identified topics of concern for potential inclusion in an adaptive management strategy (**Table 2-7**). The "Related Indicators" column in the table illustrates the relationship among VECs. For example, indicators for topics of concern for Recreation overlap with those for H&S.

TABLE 2-7
Key Topics for Further Consideration in an Adaptive Management Program

VEC Topic of Concern	Related Indicators
Water Quality & Sediment Quality	
1) Legacy contaminated sediments	Measures of key water quality parameters, including dissolved oxygen, pH, fecal coliforms, turbidity, total suspended solids and nutrients
2) Bacterial contamination from CSOs	Effectiveness of specific point source control and nonpoint source control programs
3) Continued development in riparian areas	Integrity of riparian habitats – Riparian indicator
Fish	
Asian carp species moving upriver	1) Composition of fish communities, including numbers of intolerant and nonnative species, abundance and diversity 2) Level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic
Mussels	
1) Enhance knowledge of life histories for species of concern, including life histories of host fishes.	Availability of fish hosts to ensure reproductive success and maintain species diversity
2) Importance of incorporating protection of mussel habitat into site-specific permits	1) Amount of habitat with stable substrates, suitable depths, and currents and connectivity to other mussel populations 2) Measures of water quality parameters important to mussel populations
3) Characterize the habitat that best supports species of concern, including historically important sites.	1) Amount of habitat with stable substrates, suitable depths, and currents and connectivity to other mussel populations 2) Extent of food supplies to help ensure good growth rates and reproduction
4) Restore habitats and reintroduce species of concern to suitable areas.	1) Availability of fish hosts to ensure reproductive success and maintain species diversity 2) Amount of habitat with stable substrates, suitable depths, and currents and connectivity to other mussel populations 3) Extent of food supplies to help ensure good growth rates and reproduction

VEC Topic of Concern	Related Indicators
5) Conduct searches for additional populations of species of concern.	1) Availability of fish hosts to ensure reproductive success and maintain species diversity 2) Amount of habitat with stable substrates, suitable depths, and currents and connectivity to other mussel populations 3) Extent of food supplies to help ensure good growth rates and reproduction
6) Enforce all laws and regulations pertaining to collection of specimens and protection of habitat.	Potentially related to all mussel indicators
7) Identify the potential effects and responses to zebra mussel and Asian carp invasions and their control measures.	Extent of disturbance from biotic stressors, such as invasive zebra mussels and from abiotic stressors, such as river traffic
8) Increase public and agency awareness of existing laws that protect mussels.	Potentially related to all mussel indicators
9) Use media opportunities to reach the general public and encourage involvement in the recovery process.	Potentially related to all mussel indicators
Riparian/Floodplain Resources	
1) Continued fragmentation and loss of riparian resources	Integrity of riparian habitats
2) Need for institutional coordination for riparian area management, including: a. Requiring impact identification and mitigation by NEPA b. Designation of special management areas on public lands c. Regulation of activities on privately-owned riparian areas d. Utilization of incentives to encourage use of BMPs, and e. Purchase of privately owned lands for public management	Related to all riparian indicators: 1) adequacy of hydrologic connections between riparian areas and adjacent water bodies and uplands 2) capacity for water storage in floodplain 3) quality of soil structures 4) adequacy of water table and groundwater recharge 5) sustainability of sediment dynamics 6) capacity of riparian areas to intercept pollution 7) integrity of riparian habitats and 8) measures of biodiversity
Air	
Establishment of more effective limits for mercury emissions	Potential sources of contamination associated with past or present activities – Health & Safety indicator
Health & Safety	
1) Growing potential conflicts among recreation, commercial and navigation river users	1) Number of accidents associated with commercial or recreational boating 2) Quality of experience related to river conditions (e.g. density of watercraft, safety concerns) - Recreation indicator
2) Need to eliminate CSOs and SSOs	1) Potential sources of contamination associated with past or present activities 2) Effectiveness of specific point source control and nonpoint source control programs - Water Quality indicator

VEC Topic of Concern	Related Indicators
3) Reduction of mercury emissions from coal-fired power plants	Potential sources of contamination associated with past or present activities
4) Clarification of fish consumption advisories	Number and types of public advisories related to boating, swimming and fish consumption
Recreation	
1) Need to eliminate CSOs and SSOs	1) Quality of experience related to river conditions (e.g. density of watercraft, safety concerns) 2) Number and types of public advisories related to boating, swimming and fish consumption 3) Potential sources of contamination associated with past or present activities – Health & Safety indicator
2) Perception that increased participation could result in overcrowding and competition for limited resources	1) Types of recreation and associated opportunities 2) Availability of recreational-related facilities (e.g. boat launch ramps, marinas) 3) Quality of experience related to river conditions (e.g. density of watercraft, safety concerns)
Transportation &Traffic	
1) Competition over time between navigation and recreation vessels for use of locks	Average queuing times for barge traffic at locks over time
2) Amounts and types of fuels used by tows	Amounts and types of fuels used by tows vs. alternative fuels
Socioeconomics	
Need to balance long-term growth of navigation with infrastructure that supports it.	1) Barge tonnage passing through locks over time - Transportation indicator 2) Numbers of terminals and intermodal transfer facilities over time - Transportation indicator 3) Average queuing times for barge traffic at locks over time - Transportation indicator
Cultural Resources	
1) Limited eligibility of cultural resources for placement on National Register of Historic Places because of societal trends toward disposability, tear-down and sprawl.	Number of properties/sites within the study area listed or eligible for listing in the National Register of Historic Places or listed in any special state listings
2) Riverfront development, including recreation facilities, causing covering or damage to cultural resources near land surface.	1) Effectiveness of Federal regulations and SHPOs in preserving cultural resources within the study area 2) Level of efforts necessary to minimize impacts and recover artifacts and information during unavoidable past and future actions.

Opportunities to enhance ES of VECs through regulatory efforts, educational programs and societal trends also were identified through the assessment of ES and offer positive signs for ES of several VECs, as shown in **Table 2-8**. The continuation or success of such efforts and trends, however, are not assured and need to be monitored through an adaptive management program. The concepts of adaptive management and recommendations related to aquatic and riparian resources were discussed by two small working groups convened during the ORMSS process. Further information on these working groups and their recommendations are presented in CEA Chapter 13, Adaptive Management.

TABLE 2- 8
Potential Opportunities and Positive initiatives to Enhance ES of VECs

Water Quality

- Environmental impacts related to barge operation may be alleviated to some extent though implementation of nonstructural navigation improvements and technological improvements in communications and more environmentally-advanced barge design.
- Activities that support commercial navigation (e.g., port development and maintenance dredging) will continue to be scrutinized by both regulatory agencies and NGOs and may be more strictly regulated. Land disposal of in-stream dredged materials, for example, may become more common.
- Some development activity may revive or renovate underused urban space or industrial brownfields areas, with possible long-term water quality benefits related to surface and groundwater clean up.
- Increasing emphasis on pollution prevention, erosion control BMPs, and implementation of the Phase 1 and 2 NPDES programs could counteract some adverse impacts, particularly in more urban areas.
- In general, several regulatory initiatives in recent years, including TMDL development, the national CSO policy, and Phase 1 and 2 programs should measurably improve water and sediment quality, but, at this time, it is not possible to predict the magnitudes of their beneficial effects.

Fish

- Additional data on Ohio mainstem fish communities should become available through:
  1) new Section 316(a & b) studies required by the Clean Water Act,
  2) development of NAVPAT habitat assessment models, and
  3) further application and evaluation of ORFIn.
  4) incorporation of fish passage features in association with new lock construction and major rehabilitations should contribute to restoration of fish communities.

Mussels

- Implementation of additional regulatory requirements and pollution control programs should improve habitat conditions and contribute to reproductive success and community connectivity.
- Further mussel monitoring and research should enhance the databases and provide additional information for both protecting and promoting mussels.

- Fish passage improvements should help in recovery of mussel resources.

Riparian/Floodplain Resources

- Both a growing awareness of the services of riparian/floodplain services and increased demand for passive recreation along riparian corridors should be beneficial.

Recreation

- Community planning and development of recreation facilities, water quality improvements (including stormwater and CSO management), habitat protection and restoration efforts, will continue to enhance recreation experiences.

Socioeconomics

- Demographic trends indicate potential opportunities to proceed with more gradual and better planned development/redevelopment serving a more stable, established population in contrast to the earlier rapid conversion of resources to meet the demands of a rapidly expanding population.
- Waterfront development policies that support conversion of brownfields and unused or underdeveloped terminals could minimize conversion impacts to existing agricultural lands and riparian habitats.

2.13 CONCLUDING COMMENTS

In accordance with CEQ guidance for assessing cumulative effects, the CEA developed for ORMSS assessed the full direct, indirect, and contributed impacts of further modernization of the Ohio River mainstem navigation system on ten valued environmental components: water quality, fish, mussels, riparian/floodplain resources, air, health & safety, recreation, transportation & traffic, socioeconomics, and cultural resources. Four special methods consistent with the CEQ framework (described in detail in Exhibit A) were developed and applied to systematically conduct the assessment for each VEC.

The CEA went beyond its initial goal and holistically assessed the ES of each VEC as an "ultimate test" for determining the significance of cumulative effects. The resulting ES synopses and actions identified to achieve environmental sustainability of individual and interacting VECs form an important foundation for a long-term adaptive management program for the Ohio River.

Chapter 3
WATER QUALITY AND SEDIMENT QUALITY

3.1 TABLE OF CONTENTS

Definition of Water Quality

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Biological Indicators of Water Quality of the Ohio River

Attainment of Ohio River Designated Uses

Interactions with Other VECs

Relevant Actions Affecting Water & Sediment Quality

Cumulative Effects and Environmental Sustainability

Summary and Conclusions

References

3.2 DEFINITION OF WATER QUALITY

This chapter considers how cumulative effects of human use of the Ohio River have influenced water quality and what water quality impacts may be anticipated in the foreseeable future. In the Ohio River Mainstem Systems Study (ORMSS), water quality refers to the integration of physical, chemical and biological parameters of the aquatic environment and their evaluation in relation to human health and aquatic ecological resources. Water quality standards are used to assess the levels at which a particular waterbody is being protected; specific water quality parameters evaluated in the ORMSS are discussed in the section titled Indicators of Environmental Sustainability. The importance of algae, macroinvertebrates, and fish as biological indicators of Ohio River water quality also is considered in this chapter. The effects of water quality on other

important environmental components are integrated in the section titled Interactions with Other VECs.

3.3 OBJECTIVES AND SCOPE OF THE WATER QUALITY STUDY

3.3.1 Objectives

This chapter assesses the system-wide cumulative impacts on water quality of all likely major navigation improvements along the mainstem of the Ohio River during the planning period from 2000 to 2070. Impacts directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the US Army Corps of Engineers (Corps) and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFAs. These future actions include the major navigation improvements identified in this study; other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies; actions by non-governmental entities, and predictions of general economic expansion and development as well as regulatory changes.

The results of the Cumulative Effects Assessment (CEA) will lead to further consideration of:

1) the significance of impacts of the RFFAs on affected resources
2) the degree to which proposed navigation improvements contribute to those impacts, and
3) what constitutes sustainable water quality for the Ohio River mainstem.

3.3.2 Geographic Scope

The geographic focus for water quality impacts includes the Ohio River mainstem, which is most directly impacted by operation and maintenance of the navigation system, and also includes lands along either bank of the Ohio River lying "between the bluffs." This "floodplain zone" is defined as the meander channel of the Ohio River and includes the 100 and 500 year floodplains as well as terraces of level land lying above these flood zones. Floodplain lands are considered in this assessment because water quality is affected by siltation and contaminants associated with construction, industry, agriculture and other land-based activities and because interactions of the river and its floodplain are important factors in the river's ecology..

3.3.3 Time Frame

The established time frame for this project is 1920 to 2070. The earlier date approximates initiation of the Corps' lock and dam construction activities on the Ohio River while the latter date approximates the end of the 60-year planning horizon encompassed by the ORMSS. Discussion of impacts on water quality, however, requires consideration of water quality conditions before 1920. Understanding pre-1920 conditions is important in determining how the lock and dam (L&D) construction and operation contributed to subsequent changes in water quality.

3.4 ISSUES FROM SCOPING

A series of 12 public scoping meetings was held during Summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. A more detailed discussion of the scoping meetings is presented in Chapter 2 of this report.

The meetings were attended by 185 persons and over 200 verbal comments were recorded from the question and answer sessions. These comments accounted for the large majority of input. Additional comments were obtained from 19 questionnaires and several letters that were submitted.

Water quality was a major focus of the meetings. Comments that directly and indirectly addressed water and sediment quality are presented in **Table 3-1**.

TABLE 3-1
Comments from Public Scoping Meetings

Direct Comments on Water Quality	Relevance to Water Quality	Total
Methods to be used for assessing water quality	Need to accurately document baseline conditions	2
Need to consider 404 application approvals and resultant actions as direct USACE actions	Discharging of dredged and fill materials into the river	1
Increased spills and accidents potentially affecting aquatic life and impairing water quality	Lowering of WQ & damage to aquatic life	1
Cumulative effect of discharges on river may offset water quality improvements	Failure to attain WQ standards and potential damage to aquatic resources	4
Challenges to water quality presented by CSOs and SSOs	Failure to attain WQ standards and potential damage to aquatic resources	2
High levels of mercury, arsenic, fecal coliform bacteria and agri-chemicals in surface water	Failure to attain WQ standards and potential damage to aquatic resources	1
Need for more stringent discharge permitting procedures or moratorium on permits	Failure to attain WQ standards and potential damage to aquatic resources	2
Possibility of implementing mechanical aeration in mainstem pools	Need for sufficient oxygen levels for aquatic life	1
Importance of continued water quality improvements as a high priority	Need for WQ improvements to benefit aquatic life	1
Overall effects of navigation structures and activities on groundwater levels	Potential lowering of groundwater levels	1
Need to protect public groundwater supplies	Potential contamination and lowering of public groundwater levels	1
Need to improve sediment and erosion control from public and private developments	Potential turbidity and sedimentation lowering WQ & damaging aquatic life	1

Need for long-term plan to address silt removal and prevent future sedimentation	Potential turbidity and sedimentation lowering WQ & damaging aquatic life	1
Impaired water quality and bioaccumulation in fish tissue of harmful substances stirred up by dredging	Uptake of toxic substances in the food web	2
Other Comments with Implications for Water Quality	**Relevance to Water Quality**	**Total**
Need for ongoing coordination and cooperation with concerned agencies and groups	Importance of working together to achieve WQ goals	3
Other Comments with Implications for Water Quality	**Relevance to Water Quality**	**Total**
Development of ongoing program to reevaluate cumulative effects every 5 years	Need for continual WQ assessment	1
Importance of including commercial dredging and associated permitting process in CEA	Dredging causes turbidity and can damage habitats	2
Importance of coordination of resources agencies in determining baseline conditions	Need for a common under-standing of baseline conditions	2
Loss of shoreline trees and river property caused by barge activity	Potential erosion and sedimentation and increased water temperatures in localized areas	7
Effects of Greenup L/D improvements on barge queuing	Increased turbidity and sedimentation related to queuing	1
Importance of coordination between Corps and Ohio River public water suppliers	Need to ensure safe public water supplies	1
Prolonged bureaucratic procedures in obtaining discharge permits	Obstacle in achieving WQ standards	1
Bank undercutting and failure caused by increased barge traffic, queuing and wave action	Potential erosion and sedimentation lowering WQ	7
Bank erosion caused by USACE-controlled pool fluctuations	Potential erosion and sedimentation lowering WQ	3
Loss of significant farmland to urban development along river corridor	Increased polluted runoff from impervious surfaces	3
Loss of green space and wildlife habitat with development of marina facilities	Increased runoff & potential pollution from marinas	5
Development of floodplains and wetlands resulting in increased runoff and habitat loss	Increased runoff and loss of wetland filtering capacity	4
Need to develop comprehensive plans for development along river	Importance of nonpoint pollution and cumulative effects	3
Loss of unique, sensitive species due to water quality problems and habitat modifications	Reductions in aquatic life	2

Comments from public scoping meetings were reviewed as the list of RFFAs was developed for this assessment. In some manner, almost all comments in **Table 3-1** are encompassed by the RFFA list. Later in this chapter, the cumulative effects of RFFAs affecting water and sediment quality are grouped and discussed according to their impacts, which may: 1) cause turbidity and sedimentation, 2) contribute to point source pollution, 3) contribute to nonpoint source pollution or 4) contribute to pollution reduction. The comments presented in **Table 3-1** are connected to these potential impacts. For example, the first comment, which concerns Corps 404 permits, is directly related to discharge of dredged and fill materials into the river and potential turbidity and sedimentation. Similarly, most public comments can be linked to one or more of the four impacts mentioned above. These impacts are discussed in more detail in the Cumulative Effects (CE) section of this chapter.

Further, because of the interdisciplinary nature of CEA, public comments frequently are related to more than one VEC. Several comments applicable to water quality,

therefore, also apply to mussels, fish, and/or riparian resources and will appear in the public comments tables in those chapters.

3.5 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY

Indicators of Environmental Sustainability (ES), which vary by VEC, generally provide benchmarks for measuring cumulative effects on a given resource or VEC. ES indicators for water and sediment quality include:

- measures of key water quality parameters, including dissolved oxygen, pH, fecal coliforms, turbidity, total suspended solids and nutrients
- level of conformance with state and federal water quality standards, including attainment of permissible use designations
- TMDL (total maximum daily load) implementation
- effectiveness of specific point source control and nonpoint source control programs
- ability to sustain diverse, healthy populations of aquatic organisms, and
- effectiveness of spill response, monitoring programs, and related precautionary measures.

Key water quality parameters discussed in further detail in the section titled "Past to Current Baseline Conditions" include dissolved oxygen, fecal coliform bacteria, turbidity, total suspended solids, nitrogen, and phosphorus. These indicators were selected because of their importance in characterizing water quality relative to aquatic ecological resources and public health and the availability of long-term data. Information on specific water quality indicators is followed by a brief discussion of the "Ohio River's Use Designations."

3.6 LAWS, REGULATIONS, ORDINANCES AND PROGRAMS

An important regulatory event for the Ohio River's water quality and other aquatic ecological resources was the signing of an interstate compact in 1948 that created the Ohio River Valley Water Sanitation Commission (ORSANCO). The principal mission of ORSANCO was to abate existing pollution and control future pollution of waters in the Ohio River basin (ORSANCO 1998).

Because less than one percent of sewered communities along the Ohio River treated their wastewater in 1948, one of ORSANCO's first actions was to adopt and promote standards for sewage treatment. Another milestone occurred in 1970 when ORSANCO adopted its first Pollution Control Standards, which required all municipal treatment plants along the Ohio River to provide at least secondary treatment of wastewater. These standards were adopted two years before secondary treatment became mandatory under the Federal Clean Water Act (CWA) of 1972.

Every three years since 1970, ORSANCO has revised its Pollution Control Standards for all municipal and industrial discharges to the Ohio River, as changing conditions require. These standards are enforced by ORSANCO's member states, primarily through permits issued under the National Pollutant Discharge Elimination System (NPDES) in Section 402 of the CWA. Provisions of the ORSANCO compact

require state standards for discharges to the Ohio River to be at least as stringent as the commission's Pollution Control Standards. Over the decades since its creation, ORSANCO's programs have broadened to include a spectrum of monitoring activities that help track changes in biological communities and provide a database for environmental decision-making.

In addition to ORSANCO's standards, several key governmental regulations and related initiatives influence water quality in the study area. **Table 3-2** presents information on important federal regulations and established programs, which directly or indirectly influence water quality in the Ohio River.

TABLE 3-2
Laws, Regulations, Ordinances, And Programs Relevant to Water Quality

Law/Program	Key Components	Relevance to Water Quality
Clean Water Act (CWA) (U.S. Environmental Protection Agency)	Establishes structure for regulating pollution discharges into U.S. waters (NPDES permits) Gives EPA authority to implement pollution control programs Requires establishment of water quality standards Recognizes need to address nonpoint source pollution	Provides a comprehensive framework for water quality improvement and protection applicable to all waters of the United States
National Environmental Policy Act (NEPA) (Council on Environmental Quality and other resource agencies)	Requires preparation of environmental impact assessments for new construction projects and other actions with significant environmental impacts by private and governmental agencies.	Includes water quality impacts of new projects along the Ohio River such as power plants, Corps projects and riverfront developments.
Safe Drinking Water Act (SDWA) (U.S. Environmental Protection Agency)	Provides for establishment of primary regulations for the protection of public health and secondary regulations related to taste, odor and appearance of drinking water	Helps protect public water supplies for approximately three million people who use Ohio River as their source of drinking water
Water Resources Development Act (WRDA) (U.S. Army Corps of Engineers)	Authorizes Corps' port development, navigation, flood control and erosion control projects through the 1986 act and subsequent amendments	Contains provisions for environmental assessment and mitigation
Oil Pollution Act (U.S. Environmental Protection Agency)	Strengthened EPA's ability to prevent & respond to catastrophic oil spills	Protects RFTR from pollution & damage from oil spills.
Corps' Permitting Statutes (U.S. Army Corps of Engineers)	• Section 10 of Rivers and Harbors Act (1899) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. • Section 404 of CWA authorizes the Corps to issue permits for the discharge of dredged and fill materials into waters of the U.S..	Permits require assessment of impacts on water quality and aquatic ecological resources and mandate mitigation of adverse impacts
State Water Quality Certification (Appropriate state or interstate pollution	• Section 401 of the CWA requires certification from state or interstate water control agencies that a project is in	Provides opportunity for state or interstate scrutiny of such actions on fish and other aquatic

Law/Program	Key Components	Relevance to Water Quality
control agencies)	compliance with established effluent limits and water quality standards.	resources
Small Navigation Projects (U.S. Army Corps of Engineers)	Section 107 of Rivers and Harbor Act (1960) authorizes Corps to develop and construct small navigation projects for harbor protection.	Includes impacts of such actions on water quality
Site Remediation Statutes (U.S. Environmental Protection Agency)	Includes CERCLA, RCRA, SARA and related state program that focus on cleanup and restoration of contaminated sites.	Potentially reduces groundwater and soil pollution sources and contributions to pollution loads in the Ohio River
TMDL Program (U.S. Environmental Protection Agency)	Increasingly important section (§303) of CWA; regulates maximum pollutant load a water body can receive and still attain water quality standards.	Presents a more holistic option to water quality management than traditional "command and control" approaches.
Phase 1 & 2 NPDES Program (U.S. Environmental Protection Agency)	Also developed within the CWA, requires municipalities and certain industrial and construction sites to adopt BMPs to control nonpoint sources of pollution.	Should reduce pollution characteristics of stormwater discharges from urban and industrial zones along the Ohio River.
National CSO Control Policy (U.S. Environmental Protection Agency)	Published by USEPA, calls for communities to implement long-term plan for combined sewer overflows (CSOs) to comply with the CWA. Administered through each state's NPDES permit program.	Should reduce pollution from a major urban source.
Spill Response (U.S. Coast Guard & ORSANCO)	Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the CWA..	Minimizes adverse impacts of spills and discharges on mussels and other aquatic life and on water quality
ORSANCO Monitoring (ORSANCO)	Encompasses ongoing water quality and aquatic ecology monitoring programs by the ORSANCO.	Helps track trends in water quality and biological communities and provides database that can inform environmental decision-making

3.7 PAST TO CURRENT BASELINE CONDITIONS FOR CHEMICAL/PHYSICAL INDICATORS AND SEDIMENTS

Limited background information prior to the ORMSS timeframe indicates that water quality in the Ohio River probably declined between 1820 to the 1940s in proportion to population growth and industrial development in the watershed (Pearson 1992). For much of the first half of the 20th century, the Ohio River was treated as an open sewer (ORSANCO 1984).

Pearson noted that overall mean turbidity, dissolved solids, chlorides, nitrates, and sulfates of the Ohio River increased up to the 1940s, while dissolved oxygen levels declined. Acid mine drainage in the upper Ohio River before 1950 contributed to depressed pH values of less than 4.0 in some reaches. Mean monthly counts of total fecal coliform bacteria often exceeded 20,000/100 ml during the same period.

The following information on baseline conditions of selected water quality indicators has been obtained from several sources over more than 60 years at many sampling locations using a variety of assessment methods. Several parameters are considered in determining ORSANCO's aquatic use designations along the Ohio River. Historical and current information on specific water quality indicators is followed by a brief discussion of the Ohio River's Warm Water Aquatic Use designations.

3.7.1 Dissolved Oxygen

Dissolved oxygen (DO) is one of the best indicators of the health of an aquatic ecosystem. Most aquatic ecosystems require 5 to 6 milligrams per liter (mg/L) of DO to support diverse populations. DO has long been an Ohio River parameter of primary concern. Monitoring and research on this parameter in the Ohio River date back to the DO surveys and model development of Streeter and Phelps (1925). DO concentrations in the Ohio River are influenced by numerous factors, including water temperatures, biochemical oxygen demand, photosynthesis, algae, travel and mixing times of pollutants, and daily fluctuations (Wellner and Dinger 1989). Sufficient DO levels, expressed as mg/l, are especially critical to fish spawning success.

ORSANCO's current minimum DO standard for the protection of aquatic life is an average of at least 5.0 mg/l for each calendar day with the minimum concentration not less than 4.0 mg/l. During the April 15 - June 15 fish spawning season, a minimum concentration of 5.0 mg/l is to be maintained at all times (ORSANCO 2003).

These ORSANCO DO standards are consistent with standards of the states along the Ohio River. However, DO standards now enforced by the states were generally designed to reflect the needs of aquatic life as reviewed by a National Technical Advisory Committee in the late 1960s, and the National Academy of Sciences/National Academy of Engineering in the early 1970s. Most state standards still reflect scientific judgment as of those dates. A classic study of DO concentrations and aquatic life conducted in the Ohio River established the notion that 5 mg/l DO was the boundary condition between little fish life and a reasonably productive community of mixed warmwater fish species (Brinley 1944 as cited in US EPA 1986). It is not an unreasonable expectation that DO goals greater than minimum boundary conditions might be established before the year 2070 end of the ORMSS study period.

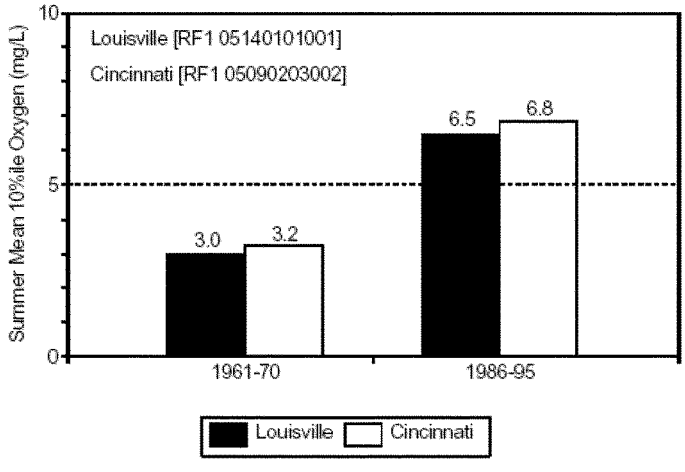
CWA antidegradation guidance (USEPA 1983) has already been applied to management of minimum DO concentrations along the Ohio River. Specifically, antidegradation policy guidance has been applied for the protection of aquatic life to hydropower development in the Ohio River basin portion of USEPA Region III (FERC 1988). Based primarily on USEPA review of numerous studies of DO effects on the survival of sensitive embryonic and larval life stages of nonsalmonid fishes (USEPA 1986), a minimum DO criteria of 6.5 mg/l was established as a lower boundary for no significant adverse impacts to warmwater fisheries.

Historically, DO levels along the Ohio River were depressed by the biochemical oxygen demand (BOD) of raw or insufficiently treated sewage discharges. In 1936, Congressman Brent Spence testified at a congressional hearing on the pollution of navigable waters that "the Ohio River is a cesspool." At that same hearing the State Health

Commissioner of Kentucky added that "the Ohio River, from Pittsburgh to Cairo, is an open sewer" (USEPA 2000). Following 1948 advances in cooperative management which included signing of the ORSANCO compact, water quality conditions in the Ohio River began to improve. Following the 1965 Federal Water Quality Act, ORSANCO adopted stream water quality recommendations. In 1970, ORSANCO Pollution Control Standard I-70 made secondary level treatment the minimum requirement for wastewater treatment plants. As a result, BOD effluent loading decreased significantly, even as influent loading continued to increase with population increases. Massive Federal cost sharing construction grants to local authorities from 1972 to 1995 helped support planning design and construction of wastewater plants to meet minimum treatment requirements. Corresponding to decreasing levels of pollutant loading, DO available in the river to support aquatic life increased substantially (USEPA 2000). **Figure 3-1** compares DO levels near Cincinnati and Louisville before and after implementation of the CWA.

Prior to effective wastewater treatment, low DO values were typically recorded downstream from the three major population centers of Pittsburgh, Cincinnati and Louisville. Until the late 1960s and mid 1970s, substantial DO sags occurred downstream of these population centers. During October and November of 1963, for example, "HydroScience" (1969), (cited in USEPA 2003) carefully documented the degree and extent of the DO sag of the Ohio River downstream of Cincinnati. At the normal bottom of the sag between miles 495 and 500, DO concentrations during this period did not exceed 2.0 mg/l. Zero DO concentrations were recorded at both miles 455 and 505. As recently as 1978, DO concentrations as low as 4.0 mg/l were occasionally reported from nearly all ORSANCO monitoring stations during June through September, when temperatures are generally highest and flows lowest. Koryak (1976), studying the upper 130 miles of the Ohio River, found development of DO stratification in navigation pools during low summer flow. Better reaeration occurred at low flows when navigation dams released water through fewer gates with larger openings to create greater turbulence.

FIGURE 3-1
Before And After Comparison of Summer Mean 10th Percentile DO Near Louisville, KY (RM 364-368) and Cincinnati (RM 460-470) During 1961-70 and 1986-95



SOURCE: USEPA (STOrage and RETrieval Water Quality Information System).

Since the completion of secondary sewage treatment facilities at most major cities in the late 1970s, few low oxygen events occur unless wastewater treatment facilities are temporarily shut down for repairs, maintenance or emergencies (Pearson and Krumholz 1984). By 1987, Wellner and Dinger actually found elevated DO concentrations up to a mile downstream from major wastewater treatment plants, indicating the general effectiveness of wastewater treatment reaeration on DO. Additionally, flow augmentation from reservoirs on Ohio tributaries assists in maintaining oxygen levels and in waste assimilation.

Potential retrofit hydropower development at Ohio River navigation dams could affect DO levels in the river. At this time there are six operating hydropower facilities along the Ohio River mainstem: McAlpine RM 606.5, Markland RM 531.5, Greenup RM 341.0, Racine RM 237.5, Belleville RM 203.9, and Hannibal RM 126.4. However, increasing energy prices and favorable public policy could in the future create incentives for additional hydropower development. During the late 1980s, when such conditions occurred, nearly every navigation dam on the Ohio River and its tributaries, as well as most Federal storage reservoirs in the basin, were permitted or licensed by FERC for hydropower development.

Potential hydropower generation at the first five Ohio River navigation dams (Emsworth, Dashields, Montgomery, New Cumberland and Pike Island), in particular, could affect DO levels in the river, because diversion of river flows through turbines can interfere with the rapid introduction of oxygen which occurs when water passes over a dam. Since the 1970s, the USACE has operated these five dams to manage the energy of their discharges to promote efficient gas exchange and reaeration of discharged waters. These operations principally involve schedules of gate operations designed to promote tailwater turbulence and air entrainment during low flow periods. These operations have been very successful and have eliminated serious summer DO depressions along this reach. An additional benefit to water quality from these operations to maximize gas exchange, achieved perhaps at somewhat of a cost to local air quality, is the stripping of volatile organic compounds (VOCs) from the water discharged (FERC 1988, Koryak 1988, Kincaid et al 1988).

The Federal Energy Regulatory Commission (FERC) analyzed the potential cumulative impacts from stacked retrofit hydropower development at navigation dams along the upper 350 mile-long reach of the Ohio River (FERC 1988). The results of FERC model studies demonstrated that there would be substantial declines in dissolved oxygen concentrations from stacked hydropower projects then licensed or permitted along the upper 150 mile reach of the Ohio River during both low and moderate summer season flow periods. Essentially, this entire reach, which at present generally exceeds the minimum warmwater antidegradation DO criteria of 6.5 mg/l, would fail to meet this standard. Downstream of Willow Island Dam, adverse cumulative impacts from stacked retrofit hydropower development were predicted to be more moderate if mainstem hydropower were developed as then proposed. FERC also piggybacked a bioenergetics model on to their hydraulic/water quality model, which showed a very substantial adverse impact to fish growth in the Ohio River from the losses in DO. Again, this impact was most severe along the upper 150-mile reach of the river. DO concentrations along the longer and deeper pools downstream of Willow Island Dam do not appear to be influenced as strongly

by operations at the navigation dams, and are generally not as well aerated at low summer flows as the pools in the upper river.

At present, there are no hydropower facilities operational on the Ohio River upstream of Hannibal Dam. However, electrical energy costs and public policy changes between now and the year 2070 may again encourage additional hydropower development along the Ohio River which could influence future DO concentrations and fish growth in the river.

ORSANCO policies require hydropower developers to:

1) conduct studies to determine the level of aeration provided by the dam prior to hydropower construction,
2) replace the aeration capacity when needed to maintain river DO conditions, and
3) continuously monitor DO levels above and below the facility, with results made available to ORSANCO.

3.7.2 pH/Acidity/Alkalinity

pH is a measure of the acidic or alkaline (basic) nature of a solution as ranked on a scale to 1 to 14. pH affects many chemical and biological processes in water. Below a pH of 7.0, water is acidic; above 7.0, water is alkaline or basic. Because the pH scale is logarithmic, a drop in pH by one unit is equivalent to a ten-fold increase in acidity. Therefore, a water sample with a pH of 5.0 is ten times as acidic as a sample with a pH of 6.0. ORSANCO's current pH standard to protect aquatic life is between 6.0 and 9.0 standard units (ORSANCO 2003). Significant environmental impacts of pH involve synergistic effects with other substances (e.g., iron, aluminum, ammonia, and mercury).

Tributary waters to the Ohio River, especially the upper reaches, have historically experienced extreme variations in pH, acidity, and alkalinity. While pH values in excess of pH 9.0 maximum criteria have been observed, values depressed below pH 6.0 minimum criteria were most typical. Also, although massive dumps of acid metal pickling liquors and other episodic events have been documented, chronic acid mine drainage (AMD) from high-sulfur bituminous coal mines were primarily responsible for low pH conditions in the river.

AMD is the result of the oxidation of iron sulfides found in coal and coal underlays and overburdens. In the process of mining, these reduced minerals are uncovered and exposed to the oxidizing actions of air and water. Autotrophic sulfur and iron-oxidizing bacteria are major process catalysts of reactions, which form sulfuric acid and metal hydroxides. AMD is typically accompanied by mineralization of waters and heavy metal pollution, mostly dissolved, suspended, and/or deposited iron hydroxides and other associated absorbed and/or co-precipitated metals.

As early as 1912, the Pittsburgh Flood Commission identified AMD as a severe economic problem responsible for the corrosion of pipes, pumps, boilers, and navigation structures. By 1914 the U.S. Public Health Service had documented episodic acidification of the Ohio River as far downstream as river mile 172. Data collected by the U.S. Geological Survey and the Pennsylvania Department of Forests and Waters (White 1951) provide a record of conditions between October 1947 and September 1949, when total

acidity at Ohio River mile 17 ranged from 5 to 86 and averaged 30 mg/l as $CaCO_3$. The pH of the Ohio River ranged from 6.6 to 3.65 and averaged 5.3. Between 1940 and 1965 pH measurements of less than 5.0 (often less than 4.0) were commonly recorded in the upper 100 miles of the Ohio River. Below river mile 100, pH values usually increased gradually to mean values of 7.2 to 7.8 between Cincinnati and Cairo, river miles 463 and 981, respectively. During this same period, unusually high pH records of between 9.0 and 10.0 were occasionally seen in all reaches of the river, probably due to undocumented industrial discharges. During the 1960s and 1970s, much progress was achieved in reducing AMD pollution in the upper Ohio River Basin. The success of these efforts can be seen in the annual reports of ORSANCO for the period 1974-1980. In most of these years 100% compliance with established standards for pH were achieved at all monitoring stations in the Ohio River (Pearson and Krumholz 1984).

Unusually high pH and alkalinity values are a fingerprint of runoff from urban centers in the basin. Sewage is typically alkaline, as is runoff from paved urban surfaces. Alkaline steel mill slag leachates significantly influence the pH and alkalinity of runoff in the industrialized upper reach of the river (Koryak et al. 2002). Algal blooms during summer season low flow periods can also increase pH and alkalinity.

While it would appear that AMD problems in the Ohio River have been under control for the past several decades, much of the progress in the abatement of AMD has been achieved by mandatory treatment of the effluents of active coal mines. Treatment of these mine discharges was supposed to continue in perpetuity. However numerous mining operation bankruptcies have recently occurred, and will probably continue to occur in the future. Huge underground mining complexes have been abandoned, and are now flooding. Without intervention, these abandoned mines will eventually again discharge AMD to the waters of the upper Ohio River Basin. As of the time of this document preparation, plans of action have been developed to deal with individual problems but a basin wide solution has not occurred.

3.7.3 Fecal Coliform Bacteria

The presence of fecal coliform bacteria in aquatic environments indicates water has been contaminated with fecal matter of humans or other animals, generally from the overflow of domestic sewage or nonpoint sources of waste. At the time of contamination, the source water may have been contaminated by pathogens or disease producing bacteria or viruses, which also can exist in fecal material. Consequently, the presence of fecal coliforms is an indicator of a potential health risk for humans exposed to such water.

Typhoid fever statistics presented by Drake (1931) for the period between 1873 and 1930 show that, historically, human health in the Ohio River valley was severely threatened by fecal pollution. In 1907, for example, Pittsburgh typhoid fever cases and death rates were 1,119.2 and 125.2 per 100,000 inhabitants per year, respectively. Water filtration systems of river sources of public water supplies were constructed between 1907 and 1914, and by 1914 typhoid cases and death rates dropped dramatically to 64.5 and 15.4 per 100,000, respectively. Ironically, sixty years earlier on October 25, 1847, James H. Laning of Cincinnati had appeared before Pittsburgh Common Council to propose filtration of public water supplies. By 1930, typhoid cases and death rates had further declined to 11.2 and 1.5 per 100,000, respectively. Filtration treated only intake waters. Bacteriological pollution of the river later declined with the improved wastewater

treatment described in the previous section. Today, primary water born gastrointestinal human diseases of concern include giardiasis and cryptosporidiosis. Also, amoebic meningoencephalitis from thermophilic *Naegleria fowleri* is a unique potential health problem in the thermal discharges, recipient waters, and cooling towers of the numerous power plants along the Ohio River. Data developed by Sykora et al. (1983) suggests that the optimum water temperature for pathogenic *Naegleria* strains in artificially heated effluents is between 27 and 35°C. While the probability that heated effluents might contaminate large bodies of generally cooler water is limited, swimming and other water contact activities are not advisable in the heated effluents and in sections of recipient waters affected by elevated water temperatures. Pearson (1992) notes that direct effects of coliform bacteria on fishes are negligible, but that sewage contamination affects fishes by altering nutrient levels, biochemical oxygen demand, DO, and suspended sediments and by adding organic compounds.

Total coliform bacteria data for the Ohio River go back more than 60 years. The Ohio River Committee, reporting on the condition of the river from 1939-1943, found mean total coliform counts exceeding 20,000/100 mL for 31 to 61 percent of the time at monitoring stations (Pearson 1992). When the ORSANCO compact was signed in 1948, only one percent of all domestic sewage was treated before being dumped into the Ohio River. In 1951, ORSANCO established its first bacterial water quality standards of <5000 total coliform bacteria per 100 mL for drinking water and <2000 /100 mL for contact recreation. By 1964, when 97 percent of the population along the Ohio River was served by primary sewage treatment, concentrations of the coliform bacteria in the upper 100 miles of the Ohio River had dramatically declined. The mean at Wheeling, W.Va., for example, was 62,000/100mL in 1952, but only 950/100mL in 1964. In the river's middle and lower reaches (where historic levels were never as high as in the upper river), however, coliform bacteria levels in 1964 remained nearly the same as in 1952-53, or had declined only slightly (Pearson 1992). The greater assimilative capacity of the middle and lower river relative to the upper river is an important factor to take into account when making comparisons of river segments. In addition, much of the population growth along the lower river occurred after 1960, which allowed for concurrent construction of wastewater treatment plant (WWTP) capacity as the population grew.

In 1970, ORSANCO began to require all municipal wastewater treatment facilities to provide secondary treatment (ORSANCO 1984). Subsequently, coliform bacteria levels in the Ohio River were expected to decline. This decline did not occur in the river overall, although decreases did occur in the upper 100 miles. Complicating matters somewhat during the 1970s, ORSANCO began reporting only fecal coliform levels as a better indicator of sewage contamination. In 1976, ORSANCO adopted the new federal drinking water standard of 2000 fecal coliforms/100mL, a standard that has remained to date. By 1978-79, ORSANCO reported nearly 100 percent compliance in the lower two-thirds of the river and compliance about 75 percent of the time in the upper 100 miles, where problems had previously been most acute (Pearson and Krumholz 1984).

After reviewing bacterial data through the 1980s, Pearson (1992) noted that the largest decreases in coliform bacteria in the Ohio River mainstem apparently occurred after primary sewage treatment facilities became operational, with the most dramatic declines reported in the upper 100 miles. Nevertheless, most violations of the drinking water standard occurred in the upper river throughout the 1980s. The primary contact recreation

standard of ≤200/100 mL, established for full-body exposure recreation (e.g., swimming and water skiing), also was violated frequently (Pearson 1992).

Only slight declines in coliform levels occurred in the lower two-thirds of the mainstem during the same time period, despite major improvements in sewage treatment facilities. The relatively small declines were attributed to sewer overflows, nonpoint sources, inadequate disinfection at treatment plants and poor secondary treatment plant operation and design. Throughout the 1980s, however, the lower two-thirds of the Ohio River usually met the contact recreation standard of ≤200 fecal coliform bacteria per 100 mL (Pearson 1992). This standard is still used in 2005.

ORSANCO coliform bacteria monthly sampling data (May 1992 - October 1999) downstream from six urban areas along the river indicated that the highest number of exceedances of the primary contact recreation standard occurred downstream from Pittsburgh, where 62 percent of samples exceeded the standard of 200/100 mL as a monthly geometric mean. **Table 3-3** indicates the lowest number of exceedances occurred downstream from Evansville.

TABLE 3- 3
ORSANCO Fecal Coliform Sampling Exceedances
May 1992 - October 1999

Urban Area	Total samples	No. exceeding standard	% exceeding standard
Pittsburgh	48	30	63
Wheeling	48	17	35
Huntington	47	17	36
Cincinnati	46	18	39
Louisville	43	13	30
Evansville	46	13	28
Source: ORSANCO. 2000a. Biennial Assessment of Ohio River Water Quality Conditions for Water Years 1998 and 1999.			

The results of wet and dry weather cross-sectional surveys of the pool of Emsworth Dam near Pittsburgh by Knauer (2001) demonstrated some impacts of precipitation and combined sewer overflows (CSOs) on bacteriologic conditions in the river near urban areas. During dry weather in the 2001 recreation season (May 15-September 30), fecal coliform concentrations generally met target goals for recreational use (≤200 CFU/100 ml). Storms with precipitation intensities of less than 0.7 inches had little lasting impacts on fecal coliform concentrations. However, more significant and persistent fecal coliform contamination occurred following storms with greater than 1.2 inches of precipitation. Areas near the river banks tended to have higher fecal coliform concentrations, and to recover less quickly than mid-channel locations. Unfortunately, most contact recreation occurs near shore. Also, local small urban streams tributary to the navigation system, while not large enough to measurably affect the mainstem, tended to be contaminated with fecal coliforms even during dry weather. Shallow bars at the mouths of these streams were observed to be fishing and recreation concentration points along the river, as were actual CSO discharge locations. The exact number of CSOs along the mainstem Ohio River in this area is probably less important than the fact that there are a total of 420 CSOs in urban Allegheny County near Pittsburgh which impact the Ohio River.

3.7.4 Turbidity and Total Suspended Solids

Turbidity and total suspended solids (TSS) both indicate the amount of solids suspended in water, whether mineral (e.g., soil particles) or organic (e.g., algae). TSS is measured by weight of material per volume of water (mg/L) while turbidity is measured as the amount of light scattered by a water sample, with more suspended particles causing greater light scattering. Turbidity is reported as nephalometric or Jackson turbidity units (NTUs or JTUs), depending on the measuring instrumentation. ORSANCO has no specific standard for TSS or turbidity. Turbidity and TSS are closely related to stream flow and velocity.

High concentrations of particulate matter in a water body can cause increased sedimentation and siltation, which, in turn, can damage habitats for fish and other aquatic life. Further, suspended particles provide attachment sites for other pollutants such as heavy metals and bacteria. Turbidity and TSS of the Ohio River are influenced by erosion characteristics of native soils and geology, but dredging for channel maintenance and land use are probably greater factors. Soil loss and runoff to waterways are accelerated by human activities such as clearing, draining of wetlands, agriculture and development. Current agricultural practices, reforestation and runoff controls from construction sites help minimize sediment losses. Simultaneously, increased nutrient loads and runoff from impervious surfaces stimulate algal productivity and increase pollutants attached to soil particles.

Qualitative reports from the 19th century describe the Ohio River as naturally clear except for the higher turbidities of the spring "freshes" (periods of flooding). Pearson and Krumholz (1984) note that Mark Twain and others described the Ohio as naturally the clearest of the three major arms of the Mississippi River system. ORSANCO reported mean turbidity values from 2 to 576 JTU for 43 Ohio River stations monitored between 1952 and 1955 and 2 to 1301 JTU monitored in 1962-63. From 1953-1985, ORSANCO observed a decreasing trend in turbidity, coinciding with the construction of numerous flood control reservoirs on major Ohio River tributaries. These impoundments trap sediments and release clearer water. According to Pearson (1992), the range of turbidities to which Ohio River fish are exposed in modern times is probably not significantly greater than in prehistoric times, but the mean turbidities are higher now. Higher mean turbidities have influenced the fish community more indirectly (e.g., by reducing favored food supplies, visibility of food organisms, and spawning areas) than directly (e.g., clogging gills, smothering eggs or larvae). Higher turbidities and concomitant siltation also have contributed to the decline of native mussels in the Ohio River mainstem.

ORSANCO's 2000 Pollution Control Standards include no specific turbidity or TSS standard for protection of aquatic life, but generally state that waters discharged to receiving waters be free from materials that will settle to form objectionable sludge deposits or suspended materials that will be unsightly or deleterious. Sewage must be treated so as not to exceed the TSS arithmetic mean in monthly samples of 30 mg/L or a weekly arithmetic mean of 45 mg/L.

3.7.5 Nitrogen and Phosphorus

Less information exists for nitrogen and phosphorus than for the other water quality metrics discussed above. Both nitrogen and phosphorus are nutrients that stimulate growth

of algae and aquatic plants that provide food for fish. Major sources of nitrogen and phosphorus entering rivers include municipal and industrial wastewater, septic systems, agricultural runoff, and atmospheric deposition. Nitrate and phosphate are the forms of these elements most readily available for plant growth. Hynes (1970) notes normal concentrations of nitrate and phosphate in river water are low because plants rapidly take up both ions.

Nitrate is the fully oxidized form of nitrogen and, except under polluted conditions, is the form normally occurring in streams. Ammonia (NH_3) is the most common form of nitrogen in sewage and is toxic to aquatic life in relatively low concentrations. In flowing water, bacteria convert ammonia to nitrites and nitrates. An ORSANCO study of long-term water quality trends from 1977 through 1987 indicated a strongly decreasing trend in ammonia nitrogen and a decreasing trend in total nitrogen, primarily related to wastewater treatment plant improvements and stringent discharge permit requirements (ORSANCO 1990).

ORSANCO water quality criteria to protect human health are 10 mg/L for nitrite + nitrate nitrogen and 1.0 mg/L for nitrite nitrogen. Recent data from 17 sampling stations between New Cumberland L/D (RM 54.4) and Paducah indicated nitrogen levels well below the standards (ORSANCO 2000a).

ORSANCO has not established a standard for total phosphorus, although USEPA recommends a maximum limit of 1.0 mg/L for flowing waters. A strongly decreasing trend in total phosphorus observed basinwide during ORSANCO's 1977-1987 long-term study was attributed to the switch to phosphate-free detergents. More recent phosphorus data were collected at 17 navigation dams for 17 dates between November 1996 and September 1999. No samples exceeded 1.0 mg/L from Hannibal L/D (RM 126.4) upstream and only a few samples exceeded that level downstream to Markland L/D. Numerous recordings above 1.0 mg/L occurred downstream from Markland L/D, primarily during the first half of 1997 (ORSANCO 2000a). These higher levels may have been related to increased runoff of agricultural chemicals.

Concerns about the effects of algal blooms on aquatic life and drinking water quality have led USEPA to direct states to adopt water quality criteria for nutrients. Algal blooms have not harmed aquatic life in the Ohio River, but drinking water suppliers have reported increased algal activity, which may result in taste and odor problems. Data from ongoing algal and nutrient analyses of Ohio River water supplies should assist in the development of appropriate nutrient criteria (ORSANCO 2001).

Depressed oxygen levels (hypoxia) in the northern Gulf of Mexico, which have caused national concern during the past decade, are attributed in large measure to heavy nutrient loads from the Mississippi Basin, including the Ohio River. Nitrate-nitrogen, associated with intensive corn and soybean production in Midwestern states, including Ohio, Indiana and Illinois, is a major factor contributing to hypoxia. Additional factors increasing delivery of nutrients to the Ohio River and its tributaries and, subsequently, to the Gulf of Mexico, include loss of wetlands and riparian areas that naturally remove nutrients, use of field drainage tile systems that accelerate agricultural runoff, atmospheric deposition, and the natural occurrence of nitrogen in Ohio basin soils. The National Science and Technology Council estimates that 44 percent of the nitrate-nitrogen reaching the Gulf of Mexico originates in the Ohio River basin (National Science and Technology

Council 2002). ORSANCO is working to develop a nutrient reduction action plan for the Ohio River sub-basin of the Mississippi basin (ORSANCO 2004a).

3.7.6 Development of Total Maximum Daily Loads (TMDLs) for Various Pollutants in the River

Total Maximum Daily Load (TMDL) refers to the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Consequently, a TMDL represents the sum of allowable loads of a single pollutant from all contributing point, nonpoint, and natural sources. The TMDL program originated from Section 303(d) of the Clean Water Act, which requires the development of TMDLs for all waters in which beneficial uses are impaired. During the 1970s and 1980s, however, TMDLs were largely overlooked as states focused on controlling point sources of pollution through NPDES permits. The present emphasis on TMDL program implementation has been driven by: 1) the realization that point source controls alone are insufficient to attain the nation's water quality goals and 2) citizen lawsuits forcing EPA to develop guidance for the TMDL program (CGER 2001).

Under USEPA regulations promulgated in 1992, states are required to identify water bodies that are not meeting water quality criteria established for specific designated uses. For each impaired water body, a state must determine the amount by which sources of point and nonpoint pollution must be reduced to meet stated water quality standards. Further, TMDL plan implementation should encompass water body restoration practices, such as habitat restoration and channel modification. Given the huge number of potential TMDLs for impaired river segments, lakes and estuaries nationwide and budget constraints, the National Research Council's Commission on Geosciences, Environment and Resources recently recommended changes to move the TMDL process forward (CGER 2001). TMDLs undergo technical review and public comment, and then are submitted to USEPA for final approval.

Within this complex regulatory and scientific context, TMDLs currently are being developed for the Ohio River. In 1995, ORSANCO initiated its Ohio River Watershed Pollutant Reduction Program to investigate specific pollutants on a watershed basis. The resulting pollutant-specific data have been valuable to TMDL development for dioxin and polychlorinated biphenyls (PCBs) in the Ohio River (ORSANCO 2001). These contaminants have been found in fish tissue at levels warranting the issuance of consumption advisories for certain fish species. The dioxin TMDL was developed in 2000 and applies to the Ohio River from Racine L/D (RM 237.5) to the Big Sandy River (RM 317). Related data indicated that dioxin levels must be reduced from the Kanawha River and Upper Ohio in order to meet water quality standards. ORSANCO is conducting sampling of fish tissue, water sediments and air to further identify sources of dioxin. A TMDL for PCBs was completed for the Pennsylvania (RM 0 – 40) and West Virginia/Ohio portions of the river (RM 40 through RM 317) during 2003 and is being implemented.

Since the completion and approval of these TMDLs, ORSANCO has been interacting with states along the Ohio River in considering the need and probability of extending both the dioxin and PCB TMDLs to include the entire mainstem. Further, ORSANCO has been collecting bacterial data along the entire river that may support the future development of a TMDL for *E. coli* (Sam Dinkins, personal communication).

3.7.7. Sediment Quality

The natural bottom substrates of the Ohio River are mainly sand, gravel, or clay overlain, especially in near shore or other sheltered areas, with silt and/or organic detritus. ORSANCO (1996) noted that fine-grained sediments are usually found at the mouths of tributaries, on river banks and near lock and dam structures. Ohio River sediments are somewhat mobile and dynamic because proportions of surficial bottom materials may be replaced with every storm event.

Bottom sediments are natural "sinks" for many toxic and persistent pollutants that enter waterways. Consequently, sediment quality can reflect historical changes in watershed economies related to industrial and agricultural activity. These deposits represent potential sources of contaminants that may reenter the water column through stream scouring, anaerobic release, and bioaccumulation, as well as through dredging for channel maintenance (Youger and Mitsch 1989).

Significant heavy metal contamination in the Ohio River has resulted from various sources including coal mine drainage with inflows of iron and manganese, and industrial activity, particularly the iron and steel industry of the upper Ohio River valley. Lyman (1987), as cited by Youger and Mitsch, mentions that even with increasing control of point and nonpoint pollution sources, sediments contaminated with heavy metals and other pollutants may continue to adversely affect overlying waters and food chains for years.

Youger and Mitsch's 1987 sediment study was conducted at 11 sites on the Ohio River, primarily upstream of navigation locks between Pittsburgh and Louisville. Samples typically consisted of fine grain silt/clay sediments taken within 100 m of the bank due to high sediment scour in the middle of the river. Concentrations of heavy metals generally decreased with distance downstream, paralleling a trend found in 1977 by ORSANCO. Lower concentrations of most metals, including cadmium, chromium, copper, iron, lead, nickel, and zinc, were associated with a dramatic decrease in the iron and steel industry in the upper river during 1977-87. The highest concentrations of barium, cadmium, copper, manganese, and nickel were found in pools immediately downstream of East Liverpool, OH (RM 54) and Wheeling, WV (RM 118-126). Chromium was highest in the pool below Steubenville, OH (RM 83). With the exception of cadmium and zinc, a slight upturn in concentrations of all metals usually occurred at RM 531 immediately upstream from Markland Dam, illustrating the effects of past and present discharges from the Cincinnati metropolitan region. Youger and Mitsch found concentrations generally were well above background and, therefore, may be a source of contamination in the river for years to come.

As the number of different water and sediment contaminants of potential concern is very extensive, practical and realistic guidance is essential in attempts at contaminant analysis and screening. In this respect, USEPA has developed several lists, one of which is its priority pollutant list. The CWA of 1977 emphasized the control of toxic pollutants and declared 65 priority pollutants to be toxic under section 307(a). This list of 65 toxic pollutants potentially included thousands of specific substances within its generic classes, many of which were then relatively unknown outside the scientific community. Also, many of these specific compounds had only rarely been examined in the environment and analytical methods to conduct monitoring for them were not available. Therefore, in order to implement the 1977 CWA and streamline its regulatory tasks, USEPA defined a high

priority list of 129 specific toxic pollutants, and subsequently (1979) developed and published approved analytical techniques. Also, the presence or absence of bulk contaminants found in sediments does not necessarily provide insight into the potential for these contaminants to reenter the water or food chain. Guidance for determination of the potential to remobilize contaminants in sediments by activities such as dredging and filling was developed initially by a USEPA/USACE technical committee in 1977 (USEPA/USACE 1977), as an implementation manual for Section 103 of Public Law 92-532 (Marine Protection, Research and Sanctuaries Act of 1972). A standard elution test of waters and sediments was one of the products of this effort. This elution test involves vigorous mixing of sediments with river water, and then analysis of the water (the elutriate) after centrifugal removal of suspended sediments.

An example of an early and informative effort to integrate the various guidances discussed above, and to apply such contaminant screening methods specifically to the sediments of the Ohio River, was a "worst case" river sediment study of the upper river conducted in 1980 (USACE 1981). In this worst case study, fine grain size, industrial legacy sediments were analyzed for USEPA designated priority pollutants in bulk sediment samples, river water samples, and sediment/river water elutriates samples. Also, 96-hour static bioassays of these sediment elutriates were conducted, under guidelines recommended by the joint USEPA/USACE Technical Committee on Criteria for Dredged and Fill Material.

The chemical data did not demonstrate a tendency for sediments to release priority pollutants to the water column with vigorous mixing. In fact, rather, there was a tendency for eluted sediments to adsorb to priority pollutant metals and remove them from the water column. This tendency was consistent with the principal findings of a study by Brannon et al. (1976), "no relationship existed between trace metal concentrations in the standard elutriate and total metal concentration in the sediments. This held true even though some sediments were apparently highly contaminated with some trace metals. This clearly suggests that sediments can be a stable sink or repository for some contaminants." As will be discussed later, the only statistically significant mortality to aquatic organisms observed in the bioassays was in a steel mill slag elutriate.

Other studies, however, have demonstrated that it is possible for some sediment contaminants to be remobilized under some hydrologic conditions. For example, severe episodic shock loads of phenols were being experienced at the Wheeling, West Virginia water intake during the 1980s. Total recoverable phenolics (TRP) concentrations in the Ohio River at the intake sometimes were in excess of 100 ppb, and created severe taste and odor problems in the city's water supply. Along with cyanides, phenolic wastes have long been associated with coking and primary metals manufacturing, but NPDES permits in place at the time and agency discharge monitoring efforts could not identify the source of the Wheeling phenol problem. Since the shock loads were mostly associated with rising hydrographs, during winter high flow periods, resuspension of river sediments was suspected to be contributing to the problem. The results of a 1988-1989 study (USACE 1989a) confirmed these suspicions. The primary source of the problem was found to be meta cresol. This phenolic compound was not released in quantities by any industrial discharger, but apparently formed as an intermediate by-product of the microbial decomposition of discharged aromatic hydrocarbons, most likely toluene from a nearby plant in Tiltonsville, Ohio. The meta cresol was apparently formed in biologically active fluff that accumulated in deep scour holes in the river, and was resuspended during rising

flow periods. Nichols et al. (1983) point out that fluid mud, an intermediate stage between mobile suspended material and mud that could be considered equivalent to the Ohio River fluff in question, is chemically important because it is a reservoir for potential toxics and a medium for chemical transfer. The Wheeling experience underscores the complexities of sediment contaminant problems in the river, and perhaps a future need for investigators to look beyond consolidated sediment deposits for potential problems.

Steel mill slag might also be considered as a category of sediment, which can influence the quality of the Ohio River. Not only have massive slag fills been used as a foundation material for extensive riverfront industrial developments in the upper Ohio River Valley (Josephson et al. 1949 and USACE 1982 and 1989b), it is also extensively utilized locally for placement of highway shoulder berms, driveway and parking lot fills, stream bank protection, and as railway grade ballast. Steel mill slags can produce mineralized and extremely alkaline leachates. In the above 1982 reference, it was noted that leachates from fresh slags could produce significant mortalities in 96-hour static bioassays. The elutriate from one 4:1 river water slag wash killed all aquatic organisms tested: fathead minnows (*Pimephales promelas*), midge larvae (*Tanytarus dissimilis*), and *Daphnia magna*. The LC_{50} (lethal concentration for 50% of organisms) for the fish and the daphnids fell in the range of 13 to 36 percent of the original 4:1 elution concentration. Further examination of this slag suggested that the caustic alkalinity of its leachate was sufficient to account for the observed mortality of aquatic organisms. The pH of a first wash, 4:1 elution of this slag, almost immediately increased to 11.2. Tributaries of the navigation system in urban/industrial Allegheny County, PA are generally mineralized and alkaline from the leachates of ubiquitous slag fills. Maximum pH values reported for Nine Mile Run and Thompson Run, two tributaries to the lower Monongahela River which drain slag dumps, were pH 11.1 and 10.4, respectively (Koryak and Stafford 2001a, and Koryak et al 2002). In the late 1960s, when coal field drainage still significantly acidified the Allegheny River, and more particularly the Monongahela River, Shapiro et al (1967) found that the Ohio River accrued significant alkalinity after flowing past the steel manufacturing complexes near Pittsburgh. Koryak et al (2002) proposed that slag leachate products contributed to this large, unexplained, alkalinity load.

Historical and ambient chemical data on industrial legacy contamination of sediments along the 981-mile Ohio River mainstream are limited. Studies which are available demonstrate that adsorptive/desorption behaviors vary for different parameters, and that sediment deposition and transport processes are complex. Therefore, any attempt at trend analysis based on this chemical data would be highly problematic. As with water quality, however, biological indicators might be expected to integrate stresses and provide insight to general sediment quality and trends. For instance, while concentrations of polychlorinated biphenols (PCBs) might be mostly undetectable or non-remarkable in the waters and sediments of the Ohio River, as will be discussed in the Attainment of Ohio River Designated uses portion of this chapter, PCB bioaccumulation in fishes is occurring. PCBs in the sediments are suspected to be contributing factors. PCBs have been found by ORSANCO (2002, 2000a) in fish tissue in sufficient concentrations to trigger consumption advisories along the entire river. Chlordane, probably mostly from termite control activities in urban centers along the river, was previously a fish consumption parameter of concern, but has recently been removed from the list of substances impairing fish consumption.

Burrowing mayflies spend their aquatic life cycle in fine grained sediment deposits, which are the most likely to be contaminated. These organisms were long absent from the upper Ohio River reach most severely degraded by industrial contaminants. Their failure to recolonize the upper river quickly in the 1970s, after water quality substantially improved and numerous previously extirpated fishes returned, suggests lingering adverse impacts from legacy sediment contamination. During the 1990s, however, small to moderate numbers of burrowing mayflies were observed in the upper five pools of the Ohio River. First in 2001, and then again in 2002, mass emergences of burrowing mayflies occurred as far upstream as Pittsburgh. These emergences suggest that the quality of the sediments of the Ohio River is improving.

3.8 BIOLOGICAL INDICATORS OF WATER QUALITY OF THE OHIO RIVER

All aquatic organisms, from minute microscopic plankton to the largest fish, reflect the water quality of their environment and, thus, potentially can serve as biological indicators of water quality conditions and trends. Smaller organisms, especially algae and macroinvertebrates, have most often been studied in this regard, in part, because of their relative ease in field collection and laboratory processing. Characterization of water quality has been the primary motivation for the biological surveys, which have been conducted along the river by ORSANCO since 1957.

Bioassessments in general may be used within a planning and management framework to prioritize water quality problems for more stringent assessments and to document "environmental recovery" following control action. Some advantages of using biosurveys identified by the Ohio Environmental Protection Agency (1988) follow:

1) Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the CWA (i.e., fishable, swimmable waters)

2) Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate stresses over time and provide an ecological measure of fluctuating environmental conditions. Assessing integrated variable pollutant inputs offers a particularly useful approach for monitoring non-point source impacts and the effectiveness of certain Best Management Practices (BMPs).

3) Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to the cost of assessing toxic pollutants, either chemically or with toxicity tests.

4) The status of biological communities is of direct interest to the public as a measure of a pollution free environment, while reductions in chemical pollutant loadings are not as readily understood by the layman as positive environmental results.

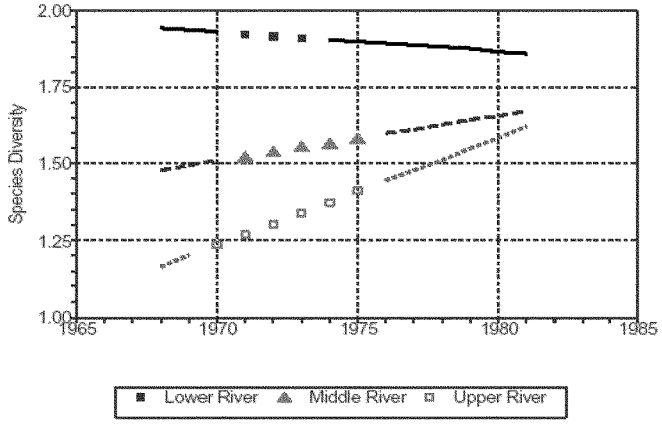
5) Where criteria for specific ambient impacts do not exist, biological communities may be the only practical means of evaluation.

3.8.1 Impacts of Water Quality on Ohio River Fishes

While the fishes of the Ohio River are discussed in Chapter 4 of this report, it is important to emphasize the strong historical link between water quality and fish inhabiting the river. An extensive inventory of the fishes of the Ohio River by investigators at the University of Louisville under the sponsorship of ORSANCO was begun in 1957 (Jackson and Weise 1962). Probably the most significant fish collections (124) were rotenone sampling of lock chambers along the river, and these rotenone sampling studies have been continued by ORSANCO almost on an annual basis since 1957. The 1957 to 1960 data represents the period when mostly primary but not secondary sewage treatment facilities were in place at communities along the Ohio River. The collections between 1967 and 1970 represent the period just preceding implementation of NEPA and the CWA. The 1974 to present period gives some idea of trends since these two important legislative initiatives were passed (Pearson and Krumholz 1984).

A 1982 review of the rotenone fish sampling data (ORSANCO 1982a) illustrates important changes, which occurred along the river between the late 1960s and early 1980s. An indication of the improving water quality in the Ohio River was the marked increase which was documented in diversity of fish species using the Shannon-Weaver index. The greatest improvements were observed in the upper reaches of the river **(Figure 3-2)**. Increases were primarily noted in sport and commercially valuable species, which tend to be more pollution-sensitive than other fish species. Fish diversity increased by 40 percent in the upper river, and 13 percent in the middle section. ORSANCO attributed the improvements to increased pH and DO concentrations, and to decreased levels of toxic materials in the river. Since 1982, additional continuing improvement, but at a somewhat reduced rate, has been observed and is discussed in Chapter 4.

FIGURE 3-2
Long-Term Trends in Fish Diversity in the Ohio River.



Source: ORSANCO 1982b.

3.8.2 Algae of the Ohio River Mainstem

Fish and mussel species have been studied and documented for the Ohio River since the 19th century; however, little is known of algae and macroinvertebrates (excluding mussels) before the mid-20th century. The following sections document algae and macroinvertebrates of the Ohio River during recent decades with implications for water quality conditions.

Algae form a basis of the food chain and are a foundational component of the Ohio River ecosystem. Not only are algae an important food source for zooplankton, mussels, and other invertebrates, but also for several species of fish which are extremely important to river ecosystems. Some shiners (*Notropis* sp.), catostomids (suckers), carpsuckers (*Carpiodes* sp.), and perhaps most critically, gizzard shad (*Dorosoma cepedianum*) are reported to feed directly and largely on algae (Hynes 1970). Algae in running waters may occur as attached forms on all types of solid objects including macrophytes and as films on mud and silt surfaces. Algae also occur as free floating or planktonic forms. Until relatively recent years, a debate ensued over whether or not apparently planktonic algae found in streams and rivers could be considered to be "truly" plankton. Hynes (1970) reviewed the literature and concluded that large rivers do support phytoplankton.

Hynes further noted that diatoms were almost always dominant. The most frequently encountered truly planktonic large river diatom genera were the pennates *Asterionella, Tabellaria, Fragilaria*, and the centric, disc-shaped forms of *Melosira, Cyclotella, Coscinodiscus*, and *Stephanodiscus*. Benthic diatoms, frequently encountered in large numbers, included the genera *Synedra, Nitzschia, Navicula, Diatoma, and Surirella*. During summer in temperate large rivers, these were joined by a variety of truly planktonic Chlorophyceae (green algae), such as *Scenedesmus, Ankistrodesmus*, and *Pediastrum*, and a variety of flagellates including *Cryptomonas*. Frequently, Cyanophyta/Cyanobacter (blue-green algae) occurred when the water was warm. Similarly, Ohio River researchers have confirmed that phytoplankton communities are very important in the Ohio River. Monitoring has to a large degree been motivated by a history of water supply taste and odor problems and public health concerns. In recent years these concerns have expanded to include control of cryptosporidious disease by filtration of the oocysts of the protozoan *Cryptosporidium parvum* during algae blooms (USACE 1994).

3.8.2.1 Ohio River Plankton Studies - 1957 to 1960

Between October 1957 and January 1960, Jackson and Weise (1962) collected 210 plankton samples along the Ohio River. Over the length of the river, they concluded that diatoms generally dominated the phytoplankton community. In particular, they found that filamentous diatoms of the genus *Melosira* were abundant, nearly ubiquitous, and a significant component of most Ohio River algae blooms. While species composition was similar along the length of the river, there were quantitative longitudinal variations, with generally depressed concentrations of phytoplankton in the polluted upper portion of the river. They suggested that acid mine drainage pollution contributed by the Monongahela River depressed phytoplankton abundance in the upper river.

A number of algae bloom events were documented at various locations between river miles 307 and 642, typically involving the diatoms *Melosira, Fragilaria*, and *Synedra ulna*; the green algae *Crucigenia* and *Dictyosphaerium pulchellum*; and the blue-green

algae *Anacystis aeruginosa*. The Louisville Water Company reported eight different taste and odor incidents lasting over a cumulative period of 136 days in 1957 and 1958. An Ohio River water supply taste and odor incident near Louisville in October 1959 was investigated by Jackson and Weise and found to have been caused by an intense bloom of *Anacystis aeruginosa*. Non-planktonic algae found growing in the Ohio River near Louisville attached to submerged objects such as sticks and rocks were *Cladophora, Oedogonium, Stigeoclonium,* and *Schizoneria*. In polluted waters near Beargrass Creek and in the municipal harbor, *Oscillatoria, Phormidium*, and *Lyngbya* were abundant.

3.8.2.2 Ohio River Plankton Studies - 1974 to 1975

The Corps (1975) sampled phytoplankton along the upper Ohio River between RM 1.0 and 129.2 in 1974. Similar to the findings of Jackson and Weise (1962), they observed that the microflora of the Ohio River was dominated by diatoms and green algae, particularly the centric diatoms *Melosira* and *Cyctotella,* and the green algae *Ankistrodesmus*. Except for a few occasional filaments of *Oscillatoria* and *Anabaena*, blue-green algae were conspicuously absent from the upper Ohio River, even during late summer. Since blue-green algae are very sensitive to acid conditions, it was speculated that the influence of acid mine drainage may have limited blue-green algae growth in the upper river at that time.

Algae concentrations at a 2 to 3 foot depth ranged from a low of 116 cells/ml in Emsworth Pool in June to 9,700 cells/ml in Hannibal Pool in September. The average for all navigation pools from June to November was more than 3,000 cells/ml. The lowest chlorophyll measurements occurred during the highest flow conditions. During a 50,000 to 70,000 cfs flow survey, total cell counts along the river were typically less than 1,000 cells/ml. During a 10,000 to 13,000 cfs low flow survey, phytoplankton total cell counts ranged from 2,000 to 9,700 cells/ml. Cell counts and chlorophyll concentrations were intermediate during moderate flow conditions. It was suggested that abundant phytoplankton in the upper Ohio River was probably related to vertical DO stratification patterns observed in the river during summer season low flow periods. The photosynthetic activity of large phytoplankton populations generates high amounts of oxygen. Light is necessary for photosynthesis and large rivers tend to carry heavy loads of suspended matter that restrict light penetration. During a July 1974 low flow survey, 50% to 80% of total incident surface light was extinct at a depth of 2 feet along the upper Ohio River. Penetration of 1% of surface light never reached 12 feet during that survey and the 1% level was only around 6 feet during a November survey. Photosynthesis, therefore, with subsequent oxygen production, is limited by light penetration to a relatively thin surface layer in the Ohio River.

Phytoplankton concentrations in near surface samples were generally elevated in the lower sections of navigation pools where velocities are low, and were reduced downstream of navigation dams. Other studies conducted by the Corps (1976 and 1991) confirm this impact of navigation dams on phytoplankton distribution. Ten surveys were conducted between 1975 and 1988 along the Monongahela River navigation system that included phytoplankton samples collected immediately upstream and downstream of navigation dams. On average, algae cell volumes decreased by 55.2% below Maxwell Locks and Dam. The mean decreases downstream of Locks and Dams No. 4, 3, and 2 were 13.5%, 20.1%, and 26.8%, respectively. These localized declines were likely the result of mixing at the dams of higher surface water algae concentrations with the lower algae

concentrations of deeper waters. A potential impact of such mixing is making fine organic materials more available to filter-feeding benthic invertebrates in the tailwaters of navigation dams than along other reaches of the navigation systems. Another observation from long term monitoring along the Monongahela River navigation system was that blue-green algae, formerly suppressed by acid mine drainage pollution, were becoming increasingly abundant as acid mine drainage pollution was abated. Blue-green algae concentrations in the Monongahela had become particularly high during summer low flow periods in the shallow, nutrient enriched, coal-fired electrical power generation thermal plumes and in the river. Blue-green algal concentrations created seasonal taste and odor nuisance problems for a major water supply utility downstream. It was suggested that thermal discharges to this lower reach of the river would be expected to generally stimulate algae growth, and selectively encourage the more thermophilic and problematic blue-green algae.

3.8.2.3 Ohio River Plankton Studies during the 1990s

No published plankton data from the 1980s are available. However, during the 1990s, Wehr and Thorp (1997) conducted a study of the effects of navigation dams, tributaries and littoral zones on phytoplankton communities in a reach of the Ohio River that extended roughly from Cincinnati to Evansville. Their study demonstrated that the Ohio River supports diverse, substantial phytoplankton communities, with densities comparable to other large rivers in North America. They observed 134 algal and cyanobacteria taxa, with about 60% of the species diversity contributed by diatoms. As with previous and subsequent investigations, cyanobacteria and green algae attained their greatest prominence in the summer, while diatoms were most prominent during the cooler months.

Wehr and Thorp concluded that Ohio River phytoplankton densities increased with temperature and decreased with current velocity. Tributaries to the study reach of the river appeared to have few effects on either phytoplankton or zooplankton, probably because of the considerably higher flow of the Ohio River relative to its tributaries in this reach. Consequently, the plankton community of the Ohio River would appear to consist of "true" resident populations. Comparison of littoral (nearshore) and pelagic (open water) habitats indicated almost no difference in phytoplankton densities. In contrast, average total densities of zooplankton were roughly 60 percent greater in littoral versus pelagic sites.

3.8.2.4 Distribution and Abundance of Phytoplankton along the Ohio River in 2002

In July 1999, ORSANCO, in cooperation with the University of Cincinnati, Northern Kentucky University and ten major public water supply utilities, initiated an ambitious program to monitor phytoplankton and chlorophyll along the Ohio River. Organisms are identified and enumerated at the genus level from samples collected twice per month, year round, at each of the ten water supply intakes **(Table 3-4)**. The most recent complete year with available organized sampling data is 2002. Chlorophyll samples are also collected and analyzed at least twice per month. Exclusive of samples that contained too much sediment to analyze, the 2002 ORSANCO phytoplankton data file contains the results of 217 phytoplankton and 366 chlorophyll samples.

TABLE 3-4
Ohio River Water Supply Intakes Sampled for Phytoplankton by River Mile (ORSANCO Data)

Supplier	River Mile
West View, PA	4.5
East Liverpool, OH	40.2
Follansbee, WV	71.0
Wheeling, WV	86.8
West Virginia American, Huntington, WV	302.0
Ashland, KY	319.7
Northern Kentucky Water Services	462.9
Louisville, KY	600.6
Evansville, IN	791.5
Paducah, KY	935.5

Table 3-5 illustrates the mean annual concentration of phytoplankton at all stations along the Ohio River in 2002 was 750 units/ml. The station with the lowest mean annual concentration was 368 units/ml at RM 86.8, and the highest was 1,859 units/ml at RM 935.5. The mean annual chlorophyll concentration at all stations along the Ohio River was 6.0 µg/l. The station with the lowest mean annual chlorophyll concentration (2.1 µg/l) was at RM 4.5, and the highest was 12.3 µg/l at RM 935.5. The tendency for concentrations of both chlorophyll and phytoplankton to increase in a downstream direction in the Ohio River during 2002 is shown in the following table.

TABLE 3-5
Phytoplankton Characteristics along the Upper, Middle and Lower Reaches of the Ohio River During 2002 (ORSANCO Data)

Characteristic	Upper Ohio River (Mile 0-299)	Middle Ohio River (Mile 300-599)	Lower Ohio River (Mile 600-981)
Mean Annual Chlorophyll Concentration (µg/l)	3.6	6.9	8.2
Mean Annual Algae Concentration (units/ml)	575	688	1,109
% Capable of Producing Taste and Odor Problems	23.7	29.3	35.9
% Tolerant of Pollution	17.4	18.7	9.7
% Diatoms	88.0	67.2	74.5
% Blue-green Algae	2.6	13.3	10.0

The percentage of phytoplankton organisms capable of producing taste and odor problems and the percentage of organisms which were blue-green algae were less in the upper river than in the middle or lower portions of the river. Conversely, the percentage of diatoms was highest in the upper river. The percentage of organisms generally considered to be tolerant of pollution was lowest in the lower river. Factors which might contribute to these spatial trends are the increasing size and lower relief of the river as it flows along its 981 mile long course, the longer navigation pools towards lower portions of the river, and warmer water temperatures in the more southerly lower reaches of the river.

Seasonal patterns apparent in the ORSANCO data show that phytoplankton is least abundant during the higher flow and colder winter months and most abundant during the lower flow and velocity warmer summer months. The mean monthly chlorophyll concentrations for all stations combined were lowest in January and February, 2.5 and 2.7 µg/l, respectively. Chlorophyll concentrations were highest in July and August, 11.0 and 10.9 µg/l, respectively.

The composition of the Ohio River phytoplankton community is complex, containing over a hundred genera. However, some generalizations can clearly be made:

- Overwhelmingly, the phytoplankton community of the river was dominated by diatoms, 88% in the upper river, 67.2% in the middle reach, and 74.5% in the lower reach. Also, pennate diatoms were much more important in the Ohio River in 2002 than centric diatoms.
- Of the pennate diatom genera, *Aulacoseira* was the dominant or co-dominant genus in 35.7% of the samples, followed by *Asterionella* (22.1%), *Skeletonema* (15.4%), *Nitzchia* (7.5%), *Fragilaria* (3.8%), *Navicula* (1.9%), *Syendra* (≤0.1%), and *Achnanthes* (≤0.1%).
- The green algae *Chlamydomonas* and *Chlorella,* and *Cryptomonas* were also occasional dominants.
- Despite the concerns related to blue-green algae blooms, blue-green algae were only dominant in 2.8% of the Ohio River samples collected in 2002. Though massive blooms of the blue-green algae *Aphanizomenon* were documented at Ashland, KY, first on July 8th and then on August 5th, 2002, these blooms appear to be more local and sporadic in occurrence than systemic.
- Differences noted in the phytoplankton community along different reaches were that centric diatoms were more abundant in the lower reach (21.5%) than in the middle or upper reaches of the Ohio River, 2.9% and 3.1%, respectively. Conversely, *Asterionella* were much less abundant in the lower river. *Nitzchia* and *Fragilaria* were substantially more abundant in the upper river than in the middle or lower reaches.

The 2002 ORSANCO length of river, year round sampling study initiative is by far the most ambitious and comprehensive attempt to monitor and characterize the phytoplankton community of the Ohio River. The results of this effort appear to be generally consistent with Hynes' (1970) characterizations of large temperate zone rivers, as well as the results of previous Ohio River phytoplankton investigations. An important possible exception to this concurrence is that in the 2002 ORSANCO data, centric diatoms, green algae, and blue-green algae taxa may have been less important along the length of the Ohio River than they had been in previous years. The use of different sampling stations and techniques in past studies make comparisons with recent ORSANCO data

somewhat speculative. However, an apparent decline in pollution tolerant and potential taste and odor causing phytoplankton organisms suggests possible improving water quality and ecological health along most of the Ohio River. Continued monitoring will allow for verification of potential trends.

3.8.3 Aquatic Macroinvertebrates of the Ohio River Mainstem

In addition to their intrinsic values and importance as food for fish and other forms of aquatic life and often non-aquatic life, benthic macroinvertebrate communities are also highly responsive indices of water quality. The advantages of using benthic macroinvertebrates for bioassessments are:

1) Macroinvertebrate communities are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well suited for assessing site-specific impacts (upstream-downstream studies).

2) Macroinvertebrate communities integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly.

3) Benthic macroinvertebrates serve as a primary food source for many recreational and commercially important fish.

4) Most state water quality agencies that routinely collect biosurvey data focus on macroinvertebrates. Many states already have background macroinvertebrate data (OEPA 1988).

Macroinvertebrate quality evaluations are based on the principle that invertebrate communities of non-degraded streams are composed of many different types of organisms, including pollution intolerant taxa such as mayflies, stoneflies, and caddisflies (Ephemeroptera, Plecoptera, and Trichoptera, or EPT organisms). The invertebrate communities of polluted streams, on the other hand, are dominated by a small number of pollution tolerant taxa such as sludge worms and bloodworms (Annelida and Chironomidae, or AC organisms). Between the extremes are numerous organisms with intermediate tolerances.

The following discussion of Ohio River macroinvertebrates excludes freshwater unionid mussels. Although mussels are aquatic macroinvertebrates, which are of special interest in the Ohio River, they are not generally well sampled by typical invertebrate collection techniques. Mussels are discussed in Chapter 5 of this report.

3.8.3.1 Ohio River Macroinvertebrate Studies - 1957 to 1960

Between October 1957 and January 1960, ORSANCO (Jackson and Weise 1962) collected Petersen, orange-peel, and Eckman dredge invertebrate samples along the length of the Ohio River. They found the invertebrate communities of rocky substrates along the main channel of the Ohio River to then consist primarily of the coelenterate *Hydra americana*, the bryozoan *Urnatella gracilis*, the dipteran *Chironomus* sp., the copepod

Canthocamptus sp., and the protozoans *Vorticella* sp. and *Epistylis* sp., none of which are indicative of unpolluted water. The invertebrate communities of soft substrates nearer to shore were even more depauperate, consisting only of very pollution tolerant tubificid worms and a few specimens of the bloodworm chironomid *Tendipes* sp.

More intensive sampling near the intake of the Louisville Water Company at RM 600 confirmed that the distribution of benthic organisms in the Ohio River was related to its substrate type. Similarly, Thorp (1992) demonstrated that invertebrate taxonomic richness and density in the Ohio River is significantly influenced by substrate composition, and also references numerous supporting studies from other locations. In the sandy and clay bottom of the Ohio River midchannel, Mason et al. (1971) found the chironomid *Tendipes decorus* to be abundant. Gut analyses revealed this organism was the major food item of many smaller fishes. Stomachs of young channel catfish and freshwater drum and silver chub contained large numbers of these larvae. The midge larva *Procladius* was found in deep sediment. Other organisms of this particular bottom type included tubificid oligochaetes, several species of *Pisidium* clams and a few unionid mussels.

Rocky bottoms contained a strikingly different fauna comprised predominantly of triclad flatworms, leeches, crayfish, aeschmid dragonfly naiads, and other aquatic insect larvae. The snail *Pleurocera canaliculatum* was found exclusively on rocky substrates. The sphaeriid clams, especially *Pisidium*, and the snails *Somatogyrus subglobosus* and *Viviparus contectoives* occurred on hard substrates, as well as sometimes large populations of *Hydra americana*, and the bryozoan *Urnatella gracilis*.

Samples of different types of bottoms and from various depths revealed fewer organisms on bottoms of sand or sand and silt than on bottoms of silt alone. For example, on March 30, 1959, a sample from a bottom of sand and silt along the Kentucky shore at mile 602.1 contained 129 organisms/m^2, while on the same date a silt bottom along the Indiana shore at mile 602.1 yielded 73,100 tubificid worms/m^2. Jackson and Weise emphasized that only a few specimens of Ephemeroptera (mayflies) were found in the Ohio River during their 1957 to 1960 study period. Ephemeroptera are generally considered to be indices of good water quality, and burrowing species of the genera *Ephemera* and *Hexagenia* are indices of both good water quality and sediment quality. They may be present in huge numbers in large unpolluted rivers where they are important components of the aquatic ecosystem and can be major sources of forage for fishes and other aquatic life. Jackson and Weiss commented that Ephemeroptera were very sparse at that time in the Ohio River compared to the large numbers then present in the Mississippi River.

It is interesting to note, that due to water quality improvements over the more than four decades since completion of the Jackson and Weise survey, burrowing mayflies have gradually returned to the entire Ohio River. Huge, newsworthy, emergences of burrowing mayflies finally returned to the Pittsburgh reach of the Ohio River only in 2002/2003.

3.8.3.2 Ohio River Macroinvertebrate Studies - 1963 to 1967

The results of an intensive Ohio River cooperative aquatic macroinvertebrate monitoring effort, conducted between 1963 and 1967, were published by U.S. Environmental Protection Agency in 1971 (Mason et al.). This effort included artificial substrate sampling (rock baskets). As was clearly demonstrated by Jackson and Weise

(1962), Thorp (1992), and many other studies not specific to the Ohio River, site-specific variations in natural substrate composition profoundly influence invertebrate communities. Use of standard artificial substrate sampling devices control this variable, as well as other physical challenges unique to invertebrate sample collection in large rivers. This approach also allows opportunities for legitimate and reasonable comparisons between different sampling stations, which can be utilized for water quality assessments of patterns and trends.

Important conclusions developed by Mason et al were that artificial substrate sampling techniques tended to collect more diverse samples than dredge samples and that during the five year study period the abundance and diversity of macroinvertebrates increased at stations along the lower and middle reaches of the Ohio River, but not yet in the upper reach of the river near Pittsburgh. Throughout 1963-67, dredge samples from the upper part of the river contained only pollution-tolerant sludgeworms and a few bloodworms. Occasionally damselflies and midges were collected from the artificial substrate samplers. Caddisflies first appeared at Toronto, Ohio (RM 58); mayflies were first present at RM 260 near Addison, Ohio; and stoneflies occurred at Huntington, West Virginia (RM 301). The invertebrate taxa found to be nearly ubiquitous along the Ohio River were the midges *Dicrotendipes nevosus*, *Procladuis* sp., *Coelotanypus* sp., *Cricotopus* spp., *Ablabesmyia* spp., *Crytochironomus* spp., and *Psectrocladius* spp. Also present at most stations were the caddisfly *Cyrnellus fratermus*, the damselfly *Argia*, the mayfly *Stenonema*, and the coelenterate *Cordylophora lacustris*.

Taxa more limited in distribution included the midge *Chironomus riparius* (upper river), *Chironomus attenuatus* and *Xenochironomus xenolabis* (middle river), and *Tanypus* sp. (lower river). The crayfish *Orconectes obscurus* occurred in the upper river and *O. rusticus* in the middle river. The pollution intolerant caddisflies *Potamyia flaxa* and *Hydropsyche orris*, stoneflies *Isoperla bilineata* and *Acroneuria* spp., the mayflies *Hexagenia* and Caenidae, and the dragonfly *Neurocordulia* sp., were restricted in distribution to the middle and lower reaches of the Ohio River.

3.8.3.3 Invertebrate Community Condition Scores - Patterns and Trends

Including the Mason study data, ORSANCO has Ohio River rock basket sampler aquatic macroinvertebrate data from 1964 to 1974, and Hester-Dendy multiple-plate artificial substrate sampler data from 1975 to 2001. The older rock basket data predates the CWA of 1972 and numerous other landmark national and local environmental initiatives, including, for instance, the 1974 initiation of secondary level sewage treatment by the Allegheny County Sanitary Authority at Pittsburgh. Of this baseline historical data, 1967 is a particularly interesting year because triplicate rock basket samples were collected at ten stations spaced along the entire length of the Ohio River between RM 6.2 and 980.4. Going back to the raw 1967 data and applying subsequently developed Rapid Biological Assessment (RBA) condition score rating analysis methodologies developed by the USEPA (Plafkin et al 1989) and the OEPA (1988) would allow for a comparison of relative invertebrate community impairment along the length of the river.

Unfortunately, most of the world's large rivers have scarcely been examined from an ecological perspective (Thorp 1992). Lotic research has rather focused on smaller and medium sized unregulated streams and rivers, and indeed only about 4% of the publications on running water have dealt with large rivers (Hynes 1989 in Thorp 1992). Therefore, there

has been little research and there is a lack of scientific consensus on appropriate metrics to use for rating impairment of large rivers. Currently, a draft index is being refined that uses benthic macroinvertebrates to assess biotic integrity in the Ohio River (Emery 2003). However, until such research is completed and consensus is reached, the following expedited attempt at rating the degree of impairment of the Ohio River invertebrate community must be considered highly tentative.

Table 3-6 shows the tentative condition scores developed from the 1967 data for ten rock basket sample collection stations along the Ohio River, as well as the metrics used to compute these scores. Only a few standard, simple, and non-controversial metrics were utilized. These include % EPT (Emphemeroptera, Plecoptera, and Tricoptera) organisms and % not AC (Annelida and Chironomidae) organisms. With no other large non-impaired river in the ecoregion to use as a reference, the reference used for the % taxa richness metric was the high diversity Ohio River station near Evansville, Indiana (RM 787.5). Because of the frequent poverty of numbers of invertebrates of any sort unanimously noted by all previously referenced Ohio River researchers, a metric was also deemed necessary to acknowledge invertebrate paucity and to reward productivity. Invertebrate paucity is likely related to the mix of historic pollution sources to the Ohio River, which have included not only domestic wastes, but also gross heavy industrial and chemical manufacturing wastes, and massive loads of acid mine drainage from bituminous coal mines. While organic waste and nutrient pollution typically result in large numbers of only a few tolerant taxa, acid mine drainage and other types of pollution can result in both drastically reduced species richness and standing crops (Koryak et al 1972, and Koryak et al 1998a). Number of organisms per sample metrics have been successfully used to rate impairment in streams influenced by acid mine drainage, urban runoff and active and legacy industrial pollution (Koryak et al 1998b, Koryak and Stafford 2001a, and Corps 2000c). While the 1967 Ohio River invertebrate community condition scores (listed in **Table 3-6** and graphically shown in **Figure 3-3**) must be considered tentative depending on a future consensus of appropriate large river metrics, they are, nonetheless, highly consistent with patterns of chemical water quality degradation which are examined and discussed in previous sections of this chapter.

TABLE 3-6
Ohio River Macroinvertebrate Metrics and Expedited Condition Scores from Triplicate Rock Basket Sample Data Collected in 1967

Station Location (Ohio River Mile)	Mean # Taxa as % Reference Station (17.7)	Mean Total # Organisms	Mean % EPT Taxa	Mean % EPT Organisms	Mean % Not AC Organisms	Mean % EPT Organisms *Cyrnellus fraternus**	Expedited Condition Score
6.2	32.2	100.0	20.1	0.3	20.1	100.0	26.5
57.5	32.2	20.0	0.0	0.0	8.7	0	12.2
167.5	62.1	40.0	6.1	5.3	31.3	50.0	29.0
260.0	45.2	40.0	40.0	49.1	54.4	50.3	45.7
301.4	69.5	100.0	35.0	46.3	51.6	97.8	60.5
341.0	35.6	20.0	20.6	45.5	54.0	95.3	35.1
462.0	73.4	100.0	33.3	76.6	78.0	88.2	72.3
600.5	75.1	80.0	27.8	42.8	50.8	87.1	55.3
787.5	100.0	100.0	45.2	85.5	86.1	11.5	83.4
980.4	81.9	100.0	51.7	70.5	76.0	0.8	76.0

According to common usage of this scoring technique (OEPA 1988), an invertebrate condition score greater than 80% indicates that a stream is non-impaired, 60-79% slightly

impaired, 40-59% moderately impaired and less than 40% severely impaired. Consistent with the historical chemical water quality data, and also generally the fish data, the 1967 invertebrate condition scores range from an extremely depressed low of only 12.2% in the upper river to a high of 83.4% in the lower river. The upper river was definitely severely degraded, the middle reach of the Ohio River appeared to have been moderately to slightly impaired and the lowest reach of the Ohio River, sufficiently downstream of Louisville, Kentucky, was only slightly impaired, approaching and possibly reaching a non-impaired status. Re-initiation in 2002 of rock basket sampling by ORSANCO at 23 stations between river miles 6.2 and 436.2 provides an opportunity to assess changes in the Ohio River during the past environmentally proactive 35-year period.

Condition score and metrics for the 2002 ORSANCO data are shown later in **Table 3-7** and are plotted against 1967 condition scores in **Figure 3-3.** Twenty-two of the 2002 stations were located upstream and downstream of eleven dams on the Ohio River. For trend analysis and impairment pattern identification, these upstream and downstream of dam data sets are merged, though they will be discussed separately in subsequent paragraphs. The metrics used to develop condition scores from the 2002 data are identical to those used for the 1967 data, with two exceptions. Zebra mussels (*Dreissena polymorpha*) infested the entire length of the Ohio River in the interim between collection of the 1967 and 2002 samples. They were present sporadically in sometimes enormous numbers at stations sampled in 2002. Therefore, to make the 2002 data more consistent with pre-infestation data, the number of zebra mussels was subtracted from the 2002 total number of organism metric. Also, there are some variations in taxonomic identification definition apparent in the two data sets, especially for oligochaetes, which make using the 1967 taxa richness reference problematic for analysis of the 2002 data. Therefore, % of the mean number of taxa present per sample (21.3 taxa) was substituted as a reference station metric for the 2002 data. The results plotted on **Figure 3- 3** clearly demonstrate that dramatic improvements have occurred along the previous severely impaired upper reach of the Ohio River since 1967, but less so or not at all along the moderately to slightly impaired middle part of the river. Notwithstanding the progress to date, the plots on **Figure 3-3** for the upper and middle river, compared to the higher condition scores for the lower river, suggest that there is still considerable room for improvements along the upper and middle reaches of the Ohio River.

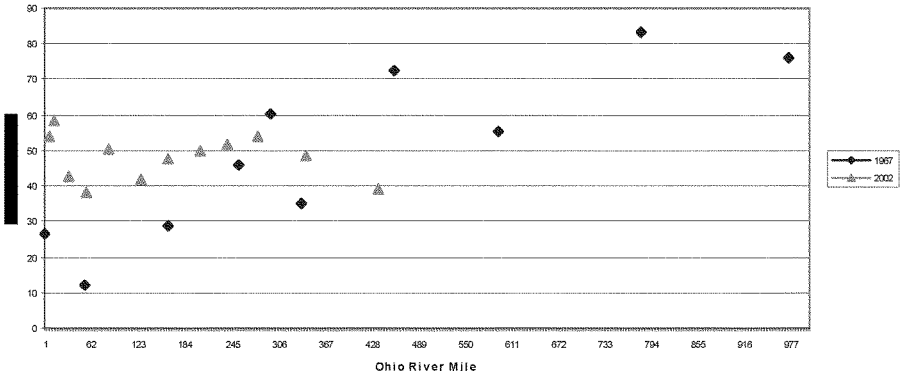
3.8.3.4 Invertebrate Signature Species

The extensive ORSANCO Ohio River aquatic macroinvertebrate data file is a unique and exceptionally valuable large river ecosystem information resource. Information mining of this file has the potential to yield numerous important insights into the ecology not only of the Ohio River, but also perhaps of other large temperate regulated rivers in general. While the examination of the file presented in this discussion should be considered to be cursory, some characteristics of the fauna are evident. Among these is the presence of certain organisms, which because of their ubiquitous distribution and/or abundance might be considered to be Ohio River invertebrate signature species. One candidate example is the net spinning, collector/filterer, and almost uniquely large river habitat caddisfly *Cyrnellus fraternus*. This organism was present in 88% of the rock basket samples examined. *Crynellus fraternus* comprised fully 58.1% of the total number of all EPT organisms collected from the Ohio River in 1967, and 39.4% of all 2002 EPT organisms. Identification of important system specific taxa, such as the crustacean

Gammerus minus and the mayfly *Baetis flavistriga* in urban drainage in the upper Ohio River Valley (Koryak et al 2003), can also be used to help refine rating metrics.

FIGURE 3-3

Ohio River Aquatic Macroinvertebrate Condition Scores Developed from Rock Basket Sample Data Collected in 1967 and 2002 by ORSANCO



3.8.3.5 Influence of Navigation Dams on Invertebrate Communities

Characteristics of invertebrate rock basket communities from samples collected by ORSANCO upstream and downstream of Ohio River navigation dams in 2002 are summarized in **Table 3-7.** These data show that taxa richness was somewhat higher downstream of the dams, a mean of 22.4 compared to 20.2 taxa per sample. Also the mean condition score (48.3% versus 46.9%) and mean % EPT taxa per sample (22.5 versus 17.8) was higher downstream of the dams. However, all other parameters demonstrated slightly more negative values downstream of dams and the data are probably inconclusive. If there are more diverse and healthier invertebrate macroinvertebrate communities in the tailwaters of the dams than within their pools, the composition of these communities is probably correlated with natural substrate. The artificial substrate sampling techniques used would not reflect such natural variations in the substrate of the river.

TABLE 3-7
Ohio River Macroinvertebrate Metrics and Expedited Condition Scores Developed from Rock Basket Sample Data Collected by ORSANCO in 2002

Station Location (Ohio River Mile)	Mean # Taxa as % Ref. Station (21.3)	Mean Total # Organisms Score (excluding zebra mussels)	Mean % EPT Taxa	Mean % EPT Organ-isms	Mean % Not AC Organ-isms	Mean % EPT Organ-isms Cyrnellus fraternus*	Expedited Condition Score	Mean Combined Condition Score
Emsworth Dam								
Above RM 6.2	100.00	100.00	13.6	1.0	78.4	64.3	58.6	54.1
Below RM 6.2	100.00	100.00	29.2	4.9	13.9	17.5	49.6	
Dashields Dam								
Above RM 13.3	94.0	100.0	20.0	10.7	68.1	75.4	58.6	58.6
Missing Sample	-	-	-	-	-	-	-	
Montgomery Dam								
Above RM 31.7	100.0	80.0	13.6	1.0	85.4	50.0	56.0	42.8
Below RM 31.7	65.7	40.0	21.4	3.9	17.5	0.0	29.7	
New Cumberland Dam								
Above RM 54.4	89.2	20.0	15.7	9.3	41.2	0.0	35.1	38.4
Below RM 54.4	100.0	80.0	15.4	2.5	10.8	62.5	41.7	
Pike Island Dam								
Above RM 84.2	70.4	20.0	26.7	51.9	62.0	17.1	46.2	50.2
Below RM 84.2	100.0	60.0	19.2	41.0	50.7	72.3	54.2	
Hannibal Dam								
Above RM 126.4	94.0	20.0	10.0	28.4	43.2	38.1	39.1	41.7
Below RM 126.4	100.0	60.0	22.7	16.3	22.5	28.9	44.3	

Station Location (Ohio River Mile)	Mean # Taxa as % Ref. Station (21.3)	Mean Total # Organisms Score (excluding zebra mussels)	Mean % EPT Taxa	Mean % EPT Organ-isms	Mean % Not AC Organ-isms	Mean % EPT Organ-isms Cyrnellus fraternus*	Expedited Condition Score	Mean Combined Condition Score
Willow Island Dam								
Above RM 161.7	100	80	18.2	25.0	36.3	41.5	51.9	47.8
Below RM 161.7	98.6	50.0	23.8	16.1	30.6	69.7	43.8	
Belleville Dam								
Above RM 203.9	75.1	80.0	18.8	36.8	43.0	66.1	50.7	49.8
Below RM 203.9	100.0	60.0	20.8	18.0	45.6	31.1	48.9	
Racine Dam								
Above RM 237.5	100.0	60.0	20.8	14.4	26.3	29.4	44.3	51.7
Below RM 237.5	100.0	100.0	29.0	29.8	36.6	2.7	59.1	
R.C. Byrd Dam								
Above RM 279.2	100	60.0	14.8	16.0	31.6	60.5	44.5	54.2
Below RM 279.2	100	100	18.2	11.5	89.1	90.9	63.8	
Greenup Dam								
Above RM 341.0	75.1	20.0	25.0	34.3	44.3	45.8	39.7	48.4
Below RM 341.0	94.0	40.0	30.0	54.5	67.0	1.5	57.1	
Meldahl Dam								
Above RM 436.2	89.2	60.0	15.8	3.7	24.4	40.0	38.6	39.0
Below RM 436.2	79.8	60.0	17.6	2.1	37.8	0.0	39.5	
* Not used as a condition score metric								

3.8.3.6 Influence of Islands on Benthic Macroinvertebrate Communities

Thorp (1992) demonstrated linkages between islands and benthos in the Ohio River, with implications for riverine management and aquatic ecosystem restoration opportunities. He studied three reaches of the Ohio River in the McAlpine Pool, and found islands to have

significant positive effects on invertebrate density and diversity that appeared to be related to changes in physical habitat characteristics. He noted that islands interrupt the deepwater regions of the Ohio River ecosystem by providing shallow-water habitats and access to different forms of food. Jahn and Anderson (1986) also found that the macroinvertebrate fauna in large rivers show significant spatial variation among different habitats within the same pool. Macrophytes growing near islands and bank shores afford greater habitat heterogeneity for benthic species. By adding a riparian zone within the river, islands serve as an additional source of allochthonous organic materials. Thorp specifically recommends island preservation and construction to foster aquatic habitat heterogeneity, and notes that island construction has been employed in several large rivers, such as the Mississippi, with consistently satisfactory results.

3.9 ATTAINMENT OF OHIO RIVER DESIGNATED USES

Section 305(b) of the CWA requires biennial water quality assessment of the degree to which surface waters are attaining their designated uses. The Ohio River has four designated uses: 1) warm water aquatic life, 2) public water supply, 3) contact recreation. and 4) fish consumption. **Table 3-8 summarizes** the three classifications ORSANCO has developed to describe attainment of these uses.

TABLE 3-8
Assessment Criteria for Ohio River Designated Uses

Aquatic Life Support
Fully supporting: No pollutant exceeds criteria in as much as ten percent of the samples collected. AND Ohio River Fish Index (ORFIn) scores do not indicate aquatic life impairment.
Partially supporting: One or more pollutants exceed criteria in as much as ten percent of the samples collected. OR ORFIn scores indicate aquatic life impairment.
Not Supporting: One or more pollutants exceed criteria in greater than 25 percent of the samples collected. OR ORFIn scores indicate severe aquatic life impairment.
Public Water Supply Use
Fully supporting: No pollutant exceeds criteria in as much as10% of the samples collected.
Partially supporting: One or more pollutants exceed human health criteria in 11-25 % of samples collected. OR Frequent intake closures are necessary to protect water supplies due to instream concentrations exceeding finished water maximum contamination levels (MCLs) OR Frequent non-routine additional treatment is necessary to protect water supplies due to instream concentrations exceeding finished water MCLs.
Not supporting: One or more pollutants exceed human health criteria in greater than 25 % of samples collected. OR Source water quality causes MCL violations which result in noncompliance with provisions of the Safe Drinking Water Act.
Contact Recreation Use
Fully supporting: Monthly average or instantaneous maximum bacteria criteria are exceeded during fewer than 10% of the recreation season months (May – October).
Partially supporting: Monthly average or instantaneous maximum bacteria criteria are exceeded during 11-25% of the recreation season months.
Not supporting: Monthly average or instantaneous maximum bacteria criteria are exceeded during more than 25% of the recreation season months.
Fish Consumption Use
Fully supporting: No fish consumption advisories are in effect.
Partially supporting: Restricted fish consumption advisories are in effect or dioxin or mercury data indicate impairment.
Not supporting: "No Consumption" advisories are in effect for all commonly consumed species.

SOURCE: ORSANCO 2002. Biennial assessment of Ohio River water quality conditions.

For this CEA, ORSANCO's three most recent biennial assessments were reviewed to gain perspective on the current status of the Ohio River's designated uses. While comparisons of biennial assessments are generally indicative of trends, some variations between assessments may occur due to modifications in sampling procedures from year to year, including the number of Ohio River miles tested.

ORSANCO assesses Ohio River warm water aquatic life support based on chemical water quality data and measurements of fish communities using the recently developed Ohio River Fish Index (ORFIn). In 1996, ORSANCO further divided the partially supporting use classification into three categories to provide additional descriptions: substantially supporting, moderately supporting, and marginally supporting. Dramatic increases in the number of Ohio River miles fully supporting warm water aquatic life have occurred since the mid-1980s.

The biennial assessment for water years 2002-2003 indicated that 779 miles (almost 80 %) of the Ohio River were classified as fully supporting the aquatic life use and 16 miles (< 2%) were classified as partially supporting because of ORFIn scores below expected values (ORSANCO 2004b). Nineteen percent of the river (186 RM) was not assessed. During the assessment for water years 2000-2001, 974 miles (99.3%) of the Ohio River were classified as fully supporting aquatic life. Only seven miles (RM 354 - 361 in the Meldahl Pool) were classified as partially supporting, possibly due to poor habitat conditions (ORSANCO 2002). During the prior assessment (water years 1998-1999), 881 miles (90%) of the Ohio River were classified as fully supporting aquatic life. Within the partially supporting use classification, 61 miles (approximately 6%) were classified as moderately supporting, and five miles (0.5%) were classified as marginally supporting. RM 546 through 607 from the Kentucky River to McAlpine L/D were classified as moderately supporting due to poor habitat conditions; RM 177 through 182 were classified as marginally supporting "due to documented incidences of substantial impairment to aquatic life." (ORSANCO 2000b) A total of 34 miles (3.5%) from Racine L/D to the Kanawha River and from the Little Miami River to the Licking River were not assessed for aquatic life support (ORSANCO 2000b). These recent data stand in sharp contrast to water years 1980-1987 when ORSANCO classified all 981 Ohio River miles as partially supporting aquatic life (ORSANCO 1988).

Similarly, ORSANCO has reported dramatic increases in the number of river miles fully supporting public water supply use since 1980-1987, when all river miles were classified as partially supporting public water supply (ORSANCO 1988). Public water supply use is assessed based on chemical water quality data collected from ORSANCO's bimonthly sampling program, bacterial monitoring, and impacts on Ohio River drinking water utilities caused by source water conditions. During the assessment for 2002-2003, 949 miles (~ 97%) of the Ohio River were classified as fully supporting the public water supply use and 32.4 miles (~3%) were classified as partially supporting. Approximately 22 miles of impairment were based on violations of bacterial stream criteria for the protection of public water supplies (ORSANCO 2004b). During the 2000-2001 assessment, 970 miles (99%) of the Ohio River were classified as fully supporting the public water supply use. In both 2000-2001 and 2002-2003, approximately 10.5 miles from RM 161.7 though 172.2, were classified as partially supporting because the criterion for phenolics of 0.005 mg/L was exceeded in more than 10 percent of bimonthly samples at the Willow Island, WV, sampling station (ORSANCO 2004b, 2002). During the 1998-1999 assessment, 977 miles (99.6%) were classified as fully supporting public water

supply. Approximately four miles (0.4%) from RM 934.5 to 938.9 were classified as partially supporting because the human health criterion for 1,2-dichloroethane was exceeded in more than 10 percent of the samples at the organic detection system station in Paducah, KY (ORSANCO 2002). Both the phenolics and 1,2-dichloroethane exceedances indicated impairment of Ohio River source water, but did not indicate impairment of finished drinking water. Results of bacteria monitoring during both the 2000-2001 and 1998-1999 period indicated no violations of stream criteria for the protection of public water supplies in the Ohio River.

Contact recreation use support is assessed primarily from data collected from May through October at ORSANCO's six recreation season monitoring stations located on the mainstem downstream of urban centers with large combined sewer systems. Presently, 52 combined sewer overflow systems (CSOs) contribute effluent to the Ohio River **(see Table 3-10)**. CSOs and other nonpoint sources, including stormwater runoff and animal waste handling practices, have been identified as significant causes of bacterial problems in the Ohio River, particularly during heavy rains. The current ORSANCO water quality criteria is not more than 200 colony forming units (CFU) per 100 mL as a monthly geometric mean or 400 CFU/100 mL in $\geq$ 10% of samples for fecal coliforms taken during a month and 130 CFU/100 mL as a monthly geometric mean or 240 CFU/100mL in any sample for *E. coli* bacteria.

As **Table 3-9** illustrates, Ohio River miles impaired for contact recreation have fluctuated during the last three biennial assessment periods, reflecting to some extent the number of river miles assessed during each period. For the 2002-2003 assessment, approximately 367 miles of the Ohio River exceeded bacterial criteria and were classified as impaired for contact recreation use. Unlike the 2000-2001 assessment, the most recent assessment not only analyzed data from the six urban centers with large combined sewer systems but also analyzed data collected every five miles from Pittsburgh to RM 630. Approximately 345 (35%) miles were not assessed in 2002-2003. During 2000-2001, approximately 40 miles (4%) of the Ohio River were classified as partially supporting contact recreation use and 136.5 miles (14%) were classified as not supporting. In contrast to 2002-2003, a much larger percentage of the river – approximately 82% (804 miles) – was not assessed. During the 1998-99 assessment, 21 miles (2%) were classified as fully supporting contact recreation, 158 miles (16%) as partially supporting and 197 miles (20%) as not supporting. The remaining 605 miles (62%) were not assessed.

During all biennial assessments for 1998 through 2003, the entire 981 miles of the Ohio River were classified as partially supporting for fish consumption (ORSANCO 2004b, 2002, 2000a). Fish consumption use support is based primarily on the states' issuance of consumption advisories and ORSANCO's fish contaminant data. During all assessments, the entire 981 miles of the Ohio River were classified as partially supporting due to the state advisory restrictions for PCBs. During 1998-1999 and 2000-2001, the majority of river miles were partially supporting due to state-issued consumption restrictions related to mercury. However, during the 2002-2003 assessment period, ORSANCO compared mercury levels in fish tissue with the mercury criterion contained in ORSANCO's 2003 Pollution Control Standards and found no impairments. Dioxin and chlordane also have been fish tissue contaminants of concern from a public health perspective. Chlordane has recently been removed from the list of substances impairing fish consumption from the Ohio River. Dioxin, however, impaired 618 river miles in 2000-2001 and 412 river miles in 1998-99. Because of widespread exceedances of the

dioxin criterion during 2002-2003, the entire river was considered impaired due to dioxins (ORSANCO 2004b).

State-by-state water use summaries for the three most recent ORSANCO biennial assessments for all designated Ohio River uses are presented below:

TABLE 3-9
State by State Use Support Summary of Ohio River Miles Impaired During ORSANCO's Most Recent Biennial Assessments

2002 and 2003					
State	**River Mile**	**Aquatic Life Use Support**	**Contact Recreation Use Support**	**Public Water Supply Use Support**	**Fish Consumption Use Support**
PA	0.0 - 40.2	0	40.2	4.0	40.2
OH-WV	40.2 - 317.1	1.8	163.5	13.5	276.9
OH-KY	317.1 - 491.1	0	106.5	0	174
IN-KY	491.1 - 848.0	11.6	57.0	14.9	356.9
IL-KY	848.0 - 981.0	2.0	0	0	133
TOTAL MILES NOT FULLY SUPPORTING USE		**16.0**	**367.2**	**32.4**	**981**
2000 and 2001					
State	**River Mile**	**Aquatic Life Use Support**	**Contact Recreation Use Support**	**Public Water Supply Use Support**	**Fish Consumption Use Support**
PA	0.0 - 40.2	0	6.2	0	40.2
OH-WV	40.2 - 317.1	0	51.6	10.5	276.9
OH-KY	317.1 - 491.1	7	28.5	0	174
IN-KY	491.1 - 848.0	0	90.4	0	356.9
IL-KY	848.0 - 981.0	0	0	0	133
TOTAL MILES NOT FULLY SUPPORTING USE		**7**	**176.7**	**10.5**	**981**
1998 and 1999					
State	**River Mile**	**Aquatic Life Use Support**	**Contact Recreation Use Support**	**Public Water Supply Use Support**	**Fish Consumption Use Support**
PA	0.0 - 40.2	0	25.4	0	40.2
OH-WV	40.2 - 317.1	5.1	109.9	0	276.9
OH-KY	317.1 - 491.1		88.8	0	174
IN-KY	491.1 - 848.0	61	84.8	0	356.9
IL-KY	848.0 - 981.0	0	46.5	4.4	133
TOTAL MILES NOT FULLY SUPPORTING USE		**66.1**	**355.4**	**4.4**	**981**
Source: ORSANCO. Biennial Assessments of Ohio River Water Quality Conditions for Water Years 2002 & 2003, 2000 & 2001, and 1998 & 1999.					

TABLE 3-10
Combined Sewer Overflows along the Ohio River

River Mile	Discharger	State	Wastewater Treatment Plant Flow (MGD)	Permitted CSOs	CSO Plan
3.1	ALCOSAN	PA	250	21	Approved
3.1	Pittsburgh	PA	N/A	217	Required
3.1	Emsworth	PA	N/A	1	Required
3.1	McKees Rocks	PA	N/A	3	Submitted
3.1	Stowe Township	PA	N/A	7	Submitted
10.2	Coraopolis	PA	3	6	Submitted
12.3	Sewickley	PA	0.9	4	Approved
14.2	Leetsdale	PA	0.775	6	Submitted
25.0	Rochester	PA	1.4	3	Submitted
25.0	Freedom	PA	N/A	3	Required
25.6	Monaca	PA	1.15	6	Submitted
37.3	Midland	PA	1.25	1	Submitted
60.1	Toronto	OH	1	8	Submitted
68.0	Steubenville	OH	6	17	Submitted
70.5	Follansbee	WV	0.5	4	Approved
71.6	Mingo Junction	OH	0.6	6	Submitted
74.7	Wellsburg	WV	1.25	10	Approved
90.8	Wheeling	WV	15	211	Approved
93.2	Benwood	WV	0.3	14	Approved
94.0	Eastern Ohio RWA	OH	6.1	47	Approved
96.5	McMechen	WV	0.3	3	Approved
102.4	Moundsville	WV	2.34	5	Approved
128.7	New Martinsville	WV	2.3	10	Approved
250.4	Pomeroy	OH	0.345	13	Submitted
251.2	Middleport	OH	0.3	13	Reviewed
265.7	Point Pleasant	WV	0.7	2	Approved
313.2	Huntington	WV	17	23	Approved
313.2	Kenova	WV	N/A	2	Approved
317.1	Catlettsburg	KY	0.5	17	Submitted
322.5	Ashland	KY	11	8	Approved
327.4	Ironton	OH	1.7	9	Submitted
328.9	Worthington	KY	0.2	3	Suspended
351.8	New Boston	OH	N/A	2	Approved
356.0	Portsmouth	OH	5	10	Submitted
378.4	Vanceburg	KY	0.41	5	Required
411.8	Maysville	KY	3.4	11	Approved
464.5	Cincinnati	OH	200	234	Approved
477.4	No. Kentucky SD1	KY	46.5	97	Approved
493.0	Aurora	IN	N/A	3	Approved
558.8	Madison	IN	3.6	7	Approved
604.1	Jeffersonville	IN	5.2	16	Approved
612.0	Louisville	KY	105	117	Approved
726.6	Tell City	IN	2.063	5	Approved
746.2	Rockport	IN	0.5	1	Approved
754.6	Owensboro	KY	18.8	12	Approved
792.5	Evansville East	IN	18	8	Approved
794.0	Evansville West	IN	20.6	15	Approved
806.0	Henderson	KY	15	13	Approved

River Mile	Discharger	State	Wastewater Treatment Plant Flow (MGD)	Permitted CSOs	CSO Plan
829.0	Mt. Vernon	IN	4.1	3	Approved
936.0	Paducah	KY	9	10	Approved
944.0	Metropolis	IL	2.05	1	Approved
979.0	Cairo	IL	1.5	3	Approved
Total CSOs				1276	

Source: ORSANCO. 2002. Biennial Assessment of Ohio River Water Quality Conditions for Water Years 2000 & 2001.

3.10 INTERACTIONS WITH OTHER VECS

The recovery of the Ohio River during the last 50 years has had far-ranging effects on almost every VEC included in this CEA. The history and public perception of water quality conditions in the Ohio River mainstem, in large measure, illustrate the complex interplay between water and sediment quality and many other VECs, including those concerning human communities. During the mid-20th century when the Ohio River was perceived almost as an open sewer; fish, mussels and other aquatic organisms declined, recreation suffered and public health and safety were compromised.

Species composition and abundance of aquatic organisms are excellent indicators of overall water and sediment quality. Many fish species that took refuge in the lower Ohio River and in the tributaries of the Ohio during the worst decades of pollution have recovered and moved upstream. Densities, biomass, and fish community diversity have increased dramatically as water quality has improved. Sport fishing has improved and increased in popularity as fish populations have increased and taste and odor problems have generally declined. Fish consumption advisories, however, are still issued for certain species along specific river segments. Increased sport fishing has enhanced perception of the river's recreational value and, in turn, has benefited local economies.

While most fish species have increased in the Ohio River mainstem, several species requiring clean, gravel substrates for spawning have declined. Freshwater mussels, the most conspicuous component of the bottom fauna, have also substantially declined both in numbers and species diversity. Five mussel species are presently federally listed as endangered and others are proposed as candidates for designation. The impacts of the recent invasion of zebra mussels have not been documented fully.

Improved water quality and associated monitoring systems (e.g. ORSANCO's early-warning spill detection system) have combined with regulatory actions to ensure safer drinking water for more than three million people that rely on the river as their primary drinking water source. Improved water quality also has led to increases in boating and contact recreation, including water skiing and personal watercraft use. Improved water quality, consequently, has stimulated increases in recreational lockages along the river, especially near the larger metropolitan areas.

Water quality also is related to aesthetics, especially with regard to appearance and odor. The improved aesthetics of water in the mainstem have helped attract people to the riverbanks for recreation and special events. Increased public interest in the river has, in turn, stimulated land use changes with potential impacts on historical and archaeological

resources, as the demand for more parks, restaurants, bike trails and other public facilities along the Ohio River has increased.

3.11 RELEVANT ACTIONS AFFECTING WATER AND SEDIMENT QUALITY

Of 87 actions included in the RFFA matrix, seven actions were ranked "high importance" while 20 actions were ranked "medium importance" for water and sediment quality. Of the remaining 60 actions, 46 were ranked "low importance" and 14 were not ranked. **Table 3-11** lists actions ranked high or medium, indicates if the action is generally beneficial (+) or detrimental (-), and lists the action's effects according to the following key:

T/S = causes turbidity and sedimentation
PS = contributes to point source pollution
NPS = contributes to nonpoint source pollution
PR = contributes to pollution reduction

Water and sediment quality of the Ohio River cumulatively reflect the river's designated uses of warm water aquatic life, public water supply, contact recreation, and fish consumption, as well as the river's role as an important national economic and transportation artery. In discussing similar large North American rivers, Sheehan and Rasmussen (1993) state the greatest challenge to large rivers clearly is to maintain ecological integrity while sustaining multiple human uses. The cumulative effects (CE) of human activities have compromised some aspects of the Ohio River mainstem's water quality, although some favorable trends have occurred in recent decades.

TABLE 3-11
RFFAs Ranked High or Medium for Water and Sediment Quality

RFFA	Net Effect	Types of Effects
Actions of High Importance		
Channel dredging/dredged materials disposal	-	T/S, NPS
Instream sand and gravel mining	-	T/S,PS
Coal utilities	-	PS, NPS
Other coal utilities	-	PS, NPS
Industrial users, excluding coal-related	-	PS, NPS
More stringent quality standards for environmental media	+	PR
Pollutant source control	+	PR
Actions of Medium Importance		
L&D operation and maintenance	-	T/S, NPS
Dry dams, other projects off mainstem	-	NPS
ERP projects - 5 categories	+	PR
Port development (Sec.107) and maintenance dredging	-	T/S
Fleeting areas/barge storage	-	T/S, PS
Terminals	-	T/S
Multi-modal sites	-	T/S
Increased traffic	-	T/S
Accidents/spills	-	PS
Floodplain sand and gravel mining	-	NPS

RFFA	Net Effect	Types of Effects
Industrial development in floodplain	-	NPS
Marina development and operation	-	T/S, NPS
Agriculture	-	NPS
Industrial wastewater discharges	-	PS
Stormwater discharges	-	NPS, PS (from CSOs)
Phase 1 & 2 NPDES program	+	PR
TMDLs	+	PR
Effluent trading	+	PR
Control of agricultural discharges	+	PR
Environmental awareness education	+	PR

The following discussion focuses on the primary effects of RFFAs ranked high and medium in the Water & Sediment Quality RFFA matrix. RFFAs are grouped according to their primary effects, but it should be understood that most actions have multiple interrelated environmental effects.

3.11.1 Actions Causing Turbidity and Sedimentation

A wide array of actions in and along the Ohio River mainstem contributes to turbidity and sedimentation. These actions are undertaken by the USACE, navigation industry, mining industry and other river users. Such actions and their importance rankings include:

- Channel dredging/dredged materials disposal (H)
- Instream sand and gravel mining (H)
- Lock and dam maintenance and operation (M)
- Port development and maintenance dredging (M)
- Terminals and multimodal sites (M)
- Fleeting areas/barge storage (M)
- Increased traffic (M) and
- Marina development and operation (M)

The environmental effects these actions have in common include disturbance or removal of bottom substrates, temporary increases in turbidity and suspended sediments, and subsequent settling out and blanketing of portions of the river bottom. Additional impacts include: 1) reduction in light penetration, which inhibits photosynthesis of algae and aquatic macrophytes, 2) interference with respiration and feeding of aquatic organisms, 3) habitat impairment or loss, and 4) resuspension of contaminants in sediments. Further, activities involving dredging or excavation may alter flow patterns depending on local channel morphology and weather conditions. Information on specific actions follows.

Channel maintenance dredging is a significant activity that continues from early spring through late fall and involves the removal and disposal of sand and gravel deposits from the navigation channel of the Ohio River to maintain a nine-foot depth. This activity not only removes natural substrates, but also results in the effective replacement of these substrates by fine-grained sediment and detritus. Past practices have generally utilized in-stream disposal of dredged materials; potential future constraints on in-stream disposal

may require land disposal of dredged materials, which would reduce water quality impacts. In some cases, dredged materials may be utilized to create new sandbars or islands that would provide additional aquatic habitat.

In-stream sand and gravel mining also involves the removal of sand and gravel deposits from the river and their subsequent transport to land or on the river. Like channel maintenance dredging, this activity potentially results in the disturbance and removal of bottom substrates, with increased turbidity and the release of contaminated sediments, followed by the redistribution of sediments, which may cover aquatic habitats, including mussel beds and other macroinvertebrate habitat. Further, when coarser substrates are dredged, they may be replaced with fine sediments and detritus that are less conducive to colonization by aquatic life. The cumulative impacts of in-stream mining are high because of the magnitude of localized impacts and the number of locations where such activity occurs.

Port development and maintenance also has potentially adverse impacts on water quality. Knowledge of potential sediment contaminants and care in handling them, as well as use of turbidity curtains to limit downstream siltation are among measures that can mitigate such impacts. The associated development of new terminals and multimodal sites and increased commercial traffic would be expected to further impact the Ohio River's water quality because of increased turbidity and release of sediment contaminants during construction of these facilities and continuing turbidity and deposition related to barge traffic during their operation.

Traffic projections prepared by the Corps indicate that barge traffic growth will occur independently of navigation improvements addressed by this study. The second generation of high-lift lock and dam projects, which was largely completed in 1980, provides sufficient capacity to meet most projected barge traffic growth (see Chapter 10, Transportation and Traffic). Therefore, it can be expected that expanded activities and development of related facilities will occur independently of navigation improvements.

Barge queuing, fleeting and storage, and dispersed barge traffic are all navigation-related actions with impacts on water quality and sediment quality. Barge queuing has the potential to cause turbidity increases due to sediment resuspension and physical damage to bottom substrates and the organisms that inhabit them. However, in a nine year study comparing two sites with differing traffic levels, Miller and Payne (1998) found that recruitment of *Amblema plicata plicata* proceeded at similar rates regardless of traffic levels. Queuing activity increases during periodic lock and dam maintenance and repair activities and, conversely, would be reduced as a result of increased lock capacities and associated decreases in lock maintenance events. The impacts of barge fleeting and storage are similar to barge queuing and also may include the release of petroleum products into the water column and their deposition in bottom sediments. Unlike queuing, fleeting and storage would not be relieved by lock expansions and, in fact, would be expected to expand in proportion to increased commercial traffic.

Another navigation-related action with potential turbidity and sedimentation impacts is the construction of lock chamber extensions. This RFFA was ranked in the matrix as "low," primarily because of minimal occurrences over the study period and mitigation measures that could be implemented, including:

- Installing turbidity curtains to surround construction areas.
- Using environmentally acceptable fill materials.
- Scheduling construction to minimize in-river activities.
- Using dewatering techniques that minimize suspended solids in the water column.
- Implementing erosion control plans that emphasize phased clearing, containment of soils, water detention and temporary reseeding of cleared sites and timely permanent revegetation.
- Installing floating mooring buoys that restrict queuing tows to the navigation channel.

Careful positioning of buoys, channel markers and other navigation aids and information systems and "green" tow design have potential for reducing the cumulative environmental effects of navigation, but the quantitative extent of these reductions is difficult to project.

Recreational activities, including the development and operation of marinas, boat launch ramps and support facilities and operation of power boats cumulatively impact water quality and sediment of the Ohio River. Because the recent growth rate of recreation appears to outpace population and development growth, river recreation and facilities that support it are predicted to continue growing in the foreseeable future.

Marina facilities tend to be concentrated in embayments, which are especially vulnerable to water quality degradation. Embayments represent a very limited resource within the Ohio River floodplain. They provide rich habitats for spawning and juvenile fish, diverse macroinvertebrate populations, and migratory birds, as well as favorable conditions for the growth of aquatic macrophytes. Dredging of embayments is generally required to maintain accessibility to marinas and/or launch ramps. The predicted growth of marinas and dredging of embayments will likely compete with or displace valued natural resources. Continuance of this trend will inevitably impact aquatic resources. Careful siting of recreational facilities and implementation of appropriate BMPs can help reduce related water quality degradation and its negative impacts on aquatic habitats. (See Marina Development and Operation below.)

3.11.2 Actions Contributing to Point Source Pollution

Point sources of pollution have been the intensive focus of pollution reduction nationwide for more than 30 years. While most point sources to the Ohio River have been cleaned up or eliminated, the following RFFAs ranked high or medium still pose potential risks to the river's water and sediment quality:

- Coal and other related industries (H)
- Industrial river users, excluding coal-related (H)
- Industrial discharges (M)
- Accidents/spills (M)
- Marina operation (M)

A number of industrial activities congregate along the Ohio River or its major tributaries and benefit directly from the availability of barge transportation and/or availability of water supplies through maintenance of navigation pools. While some industrial activities are conducted within major urban centers, much is dispersed through

less populated areas along the length of the floodplain. These include nearly 50 coal-fired electric utilities, industries utilizing coal as a fuel and/or process material, and other industries with bulk transport needs. Continued growth of these industries is expected to occur in proportion to ongoing population and urbanization/development growth within the broader economy of the Ohio Valley region and the nation in general.

Although industrial discharges to the Ohio River are highly regulated under NPDES permitting, water and sediment quality concerns remain because of the large number of industries and their high volume of discharges to the Ohio River mainstem. Potential impacts from coal utilities include thermal pollution, chemical pollution from corrosion inhibitors, and suspended fine particulates from coal piles. Industrial discharges from manufacturing sites may include suspended solids, heavy metals, and nutrient- and oxygen-demanding constituents. Industrial sites also can be sources of nonpoint pollution during construction activities or storm events, if appropriate best management practices to reduce sediment and erosion are not implemented.

Other water and sediment quality impacts related to industrial activities along the river primarily focus on transfer of potentially harmful materials and maintenance of port/docking facilities. Coal transport alone currently accounts for more than 55% of all barge traffic on the Ohio River and is projected to account for a larger percentage of traffic for the foreseeable future. Because of the coal industry's prominence, potential environmental impacts of related barge activities and spillage of coal fines and other harmful substances are particularly important.

Spills of hazardous materials during both routine navigation and product transfer also pose threats to water and sediment quality, as well as to aquatic life resources and public water supplies. Pollution from spills is generally considered short-term, but can cause serious harm depending on the amount and nature of substances released. ORSANCO's advance spill notification system and Coast Guard spill reporting procedures have ameliorated related impacts in recent years.

Marina operations are potential point sources for petrochemicals and other toxic substances used to repair and maintain watercraft. Marinas in turn support power boats and personal watercraft which cumulatively impact water and sediment quality:

- through the release of fuel, chemical pollutants, sewage, and trash related to boat operation and maintenance,
- by contributing to shoreline erosion and subsequent turbidity and siltation, and
- by inadvertently facilitating the spread of nonnative species such as zebra mussels.

Harmful impacts to aquatic life include habitat disturbance and reduction of light penetration, inhibiting photosynthesis. In some locations, disturbance of contaminated sediments may present human health risks.

3.11.3 Actions Contributing to Nonpoint Source Pollution

Nonpoint source pollution is difficult to control because it does not come from any single point of entry, but from many diffuse sources throughout the Ohio River watershed. The following RFFAs, all ranked "medium" are nonpoint sources of pollution:

- Stormwater discharges (M)

- Agriculture (M)
- Industrial development (M)
- Floodplain sand and gravel mining (M)

Stormwater discharges result from precipitation and snow melt in excess of what can infiltrate soils or be stored in small surface depressions. Compacted soils, concrete, asphalt and other impervious surfaces allow runoff to flow quickly to the Ohio River, introducing nutrients, organics, suspended solids (which contribute to turbidity and sedimentation), and toxic substances. Regulatory programs to control and reduce pollution from stormwater discharges are discussed in the following section.

Agriculture constitutes the largest land use activity by area within or adjacent to the Ohio River floodplain. Erosion of cultivated land carries suspended solids and attached fertilizers, pesticides, and herbicides to the Ohio mainstem. These pollutants not only can degrade measurable chemical parameters of water quality but can also influence species composition and abundance of algae, macroinvertebrates, and other aquatic life. Livestock waste also may enter the river, causing elevated bacteria levels. BMPs promoted through the USDA Natural Resources Conservation Service can help mitigate these impacts, but have limited effectiveness because these BMPs are largely voluntary. Most future conversions of land use in the Ohio River corridor will occur on land currently in agricultural production or in forests. Consequently, nonpoint pollution is expected to persist unless stricter regulatory controls are implemented.

Floodplain ordinances, government programs and other constraints have limited residential, commercial, and industrial development in the Ohio River floodplain in recent years; however, some level of floodplain development is expected to continue throughout the study period. Of these development types, industrial development is potentially the most extensive and is expected to continue to grow in proportion to general economic/population expansion within the broader Ohio Valley region. Many industries along the Ohio River mainstem are to some degree dependent on the existence of an efficient and reliable navigation system. Possible development impacts related to water and sediment quality include increased erosion and attendant siltation during construction and increased stormwater runoff and associated pollutants as impervious surfaces, such as driveways, parking lots, and roof tops increase.

Floodplain sand and gravel mining, as well as limestone aggregate mining, contribute to nonpoint source pollution from surface runoff of soil and fine particulates. These mining activities benefit directly from the availability of barge transport along the Ohio River, but pose additional environmental risks related to materials handling and transfer, as well as the construction and maintenance of port/docking facilities.

3.11.4 Actions Contributing to Pollution Reduction

RFFAs that contribute to pollution reduction act as countermeasures to the cumulative effects of many previous listed RFFAs. All eight actions listed as beneficial in Table 6 contribute to pollution reduction. The two RFFAs rated as "high importance" - more stringent quality standards for environmental media and pollutant source control - are very similar and include various surface water and groundwater quality standards that have existed for some time. These are promulgated by legislation, including the CWA and Safe Drinking Water Act (SDWA). It is likely that current standards for various environmental

media will become more stringent, with implications that could strengthen environmental management of the Ohio River mainstem.

Actions with implementation deadlines and realistic provisions for enforcement over a large portion of the ORMSS study area potentially have the highest impacts. The Phase 1 and 2 NPDES program exemplifies such an initiative that is currently being implemented in urban areas and industrial and development zones bordering the Ohio River. Over time, this program should generate measurable reductions in nonpoint source pollution. The TMDL program, established by Section 303 of the CWA is a holistic program for developing allowable loads for both existing and new pollutant sources. Both the Phase 1and 2 and TMDL initiatives were ranked medium in the RFFA matrix for water and sediment quality.

Effluent trading, control of agricultural resources, and environmental awareness education, also ranked medium in the RFFA matrix, are primarily voluntary initiatives that should promote more responsible environmental decision-making and, consequently, should benefit water and sediment quality and other aquatic resources. These activities and other related voluntary efforts will need significant expansion from current funding levels to produce measurable impacts within the Ohio River corridor.

Ecological Restoration Program (ERP) projects are not listed with regulatory actions in the RFFA matrix, but have potential to contribute to pollution reduction because such projects typically include improvements in water quality and aquatic habitats among their goals.

3.12 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

One of the seven environmental operating principles of the Corps is to strive to achieve environmental sustainability (ES). ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of cumulative effects can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An analysis of environmental sustainability (AES) has been and is being used in several other programmatic studies by the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps: (1) identification of "common effects" on water and sediment quality from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of indicators for ES for water quality, and their grouping, as appropriate; and (3) consideration of the "connections" between the common effects and the indicator groups. The output of the AES consists of a qualitative (descriptive) discussion of the "connections," with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions – what is the current ES for water quality, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable – the composite conditions for the selected indicators of ES for water quality do not reflect conditions that would facilitate attainment of permissible use designations in the Ohio River, nor would they sustain diverse populations of aquatic organisms in the river.

- Marginally sustainable – the composite conditions for the selected indicators of ES for water quality are such that the attainment of permissible use designations is accomplished for the majority, but not all, of the river miles in the Ohio River, and diverse populations of aquatic organisms are occurring along the majority of the river; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of water quality for the Ohio River).

- Sustainable – the composite conditions for the selected indicators of ES for water quality are such that the attainment of permissible use designations is accomplished for essentially all of the river miles in the Ohio River, and diverse populations of aquatic organisms are occurring along the majority of the river; further, the conditions of the indicators exceed regulatory thresholds, and various governmental programs are in place to control point and nonpoint pollution sources and to emphasize pollution reduction in the river.

Four common effects of multiple actions have been previously discussed in the section entitled "Cumulative Effects"; they include actions causing turbidity and sedimentation, actions contributing to point source pollution, actions contributing to nonpoint source pollution, and actions contributing to pollution reduction.

Six indicators of ES were identified earlier in the section entitled "Indicators of Environmental Sustainability", and relevant information on them have been presented in the section entitled "Past to Current Baseline Conditions." Regarding their relevance for ES, the following rationale is appropriate:

- measures of key water quality parameters

  (1) DO – related to the total organic loading from point and nonpoint sources at specific locations along the river; can also be used as a threshold indicator since the DO standard is 5.0 to 6.5 mg/l, depending upon several conditions

  (2) fecal coliforms – related to fecal matter contamination from humans or other animals, whether from point or nonpoint sources at specific locations along the river; can also be used as a threshold indicator since the standard is 2000 fecal coliforms/100 ml

  (3) turbidity and total suspended solids – related to solid material which can be attributed to point and nonpoint sources at specific locations along the river; can originate from both man-made wastewater discharges and natural erosional processes; no specific numerical standards exist for the Ohio River

(4) nutrients such as nitrogen and phosphorus – related to the total nutrient loading from point and nonpoint sources at specific locations along the river; the nitrogen standard is 10 mg/l (for nitrite plus nitrate nitrogen); no standard has been adopted for phosphorus

- level of conformance with state and federal water quality standards, including attainment of permissible use designations – water quality standards are based on various use designations, with the level of conformance representing a composite indicator of a sustainable aquatic ecological resource

- TMDL implementation – the TMDL program is for specific water quality parameters which may reflect an "overloaded" situation related to point and nonpoint sources at specific locations; implementation of the program reflects a coordinated effort to achieve appropriate water quality standards and promote a sustainable ecological resource

- effectiveness of specific point source control and nonpoint source control programs – such programs are focused on reducing pollutant discharges into the river, and thus they promote a more sustainable aquatic ecological resource

- ability to sustain diverse, healthy populations of aquatic organisms – an aquatic system which attains water quality standards while minimizing the effects of "legacy contaminated sediments" should sustain diverse populations of various organisms; further, it should attain permissible use designations.

- effectiveness of spill response, monitoring programs, and related precautionary measures – these represent both direct and indirect programs which are focused on more effective management of water and sediment quality, and thus the promotion of a sustainable aquatic ecological resource

For the purposes of this analysis, the six indicators are grouped into three tiers for the AES. The three tiers are as follows:

- first tier – "scientific measures of quality"

  (1) water quality parameters (DO, fecal coliform bacteria, turbidity, total suspended solids, N and P)

  (2) conformance with water quality standards

- second tier – "positive actions related to source control"

  (1) point source control and nonpoint source control programs

  (2) TMDL implementation

  (3) spill response, monitoring programs, and related precautionary measures

- third tier – "composite indicators of aquatic ecosystem sustainability"; this includes two measures developed from several indicators

(1) attainment of permissible use designations

(2) sustain diverse, healthy populations of aquatic organisms

Finally, the indicators and tiers are displayed into four figures, with each figure coinciding with the four groups of actions with common effects. **Tables 3-12 through 3-15** are on the following pages. **Table 3-12** relates to RFFAs causing turbidity and sedimentation. Turbidity and sedimentation represent historical water quality concerns in the Ohio River, even with the absence of specific standards. Control programs for municipal and industrial point sources have been implemented within the last several decades, while similar programs for nonpoint sources are largely in their first decade. Increased control programs, including operational measures, are expected in the future for channel dredging/dredged material disposal, and port and marine development and operation. Implementation of a TMDL program for turbidity could occur in localized reaches of the river. Further, spill-related programs and precautionary measures are expected to reduce accidental releases. As a result of these current and anticipated future source control efforts, for turbidity and sedimentation it is expected that permissible use designations will be more easily attained, thus increasing the sustainability of diverse populations of aquatic organisms.

Table 3-13 relates to RFFAs contributing to point source pollution. Of particular concern are industrial water users and dischargers who may introduce diverse chemicals and bacteria into the river. Existing point and nonpoint source control programs have already led to reductions in industrial discharges, thus increasing the possibilities for achieving conformance with water quality standards. Future source control programs may become more stringent, and TMDL requirements could be implemented for specific industrial pollutants in certain river reaches. Also, spill prevention and response programs are expected to reduce accidental point source pollution. As a result of these current and possible future point source control efforts, it is anticipated that additional river reaches will attain their respective permissible use designations, and the river itself will be able to sustain more diverse populations of aquatic organisms.

Table 3-14 denotes four RFFAs that are of medium importance relative to nonpoint source pollution. Nonpoint source control programs are being currently implemented for stormwater discharges from urban areas, and for runoff waters from industrial areas. Source control programs related to floodplain sand and gravel mining, as well as agriculture, are anticipated, although the specific requirements and their possible effectiveness are largely unknown. However, when considering the background of a minimal historical emphasis on controlling nonpoint source pollution, it does appear that the current efforts, when coupled with possible future emphases, are and will improve the ES of the aquatic ecosystem.

Table 3-15 delineates 8 RFFAs that are expected to contribute to pollution reduction in the river. Several of the listed RFFAs represent continuations of existing pollution reduction efforts. Accordingly, the sustainability of the aquatic ecosystem is expected to improve.

TABLE 3-12
AES Tiers for Actions Causing Turbidity and Sedimentation

Actions Causing Turbidity and Sedimentation	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Channel dredging/dredged material disposal (H) • Instream sand and gravel mining (H) • Lock and dam maintenance and operation (M) • Port development and maintenance dredging (M) • Terminals and multimodal sites (M) • Fleeting areas/barge storage (M) • Increased traffic (M) • Marina development and operation (M)	• Water Quality Parameters • Conformance with Water Quality Standards	• Source Control Programs (point and nonpoint) • TMDL Implementation • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain Diverse Populations of Aquatic Organisms

TABLE 3-13
AES Tiers for Actions Contributing to Point Source Pollution

Actions Contributing to Point Source Pollution	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Coal and other related industries (H) • Industrial river users, excluding coal-related (H) • Industrial discharges (M) • Accidents/spills (M) • Marina operation (M)	• Water Quality Parameters • Conformance with Water Quality Standards	• Source Control Programs (point and nonpoint) • TMDL Implementation • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain Diverse Populations of Aquatic Organisms

TABLE 3-14
AES Tiers for Actions Contributing to Nonpoint Source Pollution

Actions Contributing to Nonpoint Source Pollution	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Stormwater discharges (M) • Agriculture (M) • Industrial development	• Water Quality Parameters • Conformance with Water Quality	• Source Control Programs (point and nonpoint) • TMDL Implementation	• Attainment of Permissible Use Designations • Sustain Diverse Populations of

Actions Contributing to Nonpoint Source Pollution	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
(M) • Floodplain sand and gravel mining (M)	Standards	• Spill Response, Monitoring, and Precautionary Measures	Aquatic Organisms

TABLE 3-15
AES Tiers for Actions Contributing to Pollution Reduction

Actions Contributing to Pollution Reduction	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• More stringent quality standards for environmental media (H) • Pollutant source control (H) • ERP projects (M) • Phase 1 and 12 NPDES program (M) • TMDLs (M) • Effluent trading (M) • Control of agricultural discharges (M) • Environmental awareness education (M)	• Water Quality Parameters • Conformance with Water Quality Standards	• Source Control Programs (point and nonpoint) • TMDL Implementation • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain Diverse Populations of Aquatic Organisms

3.13 SUMMARY AND CONCLUSIONS

The CE on Ohio River water quality from past, present, and reasonably foreseeable future actions have been addressed herein. Water quality (and related sediment quality) is a VEC in the ORMSS. This resource is valued because it is interwoven with the health and sustainability of other aquatic ecological resources (such as mussels and fish), riparian resources (such as riparian habitats, wetlands, and islands), and human health (as related to the consumption of potentially contaminated drinking water and fish). Water quality in the Ohio River is influenced by land use changes associated with economic growth and development, by point source discharges of municipal and industrial wastewaters, and by nonpoint source discharges associated with urban and rural runoff. Further, both navigation traffic and recreational boating can influence the water quality VEC along with other aquatic and riparian resources. Accordingly, the geographic boundaries for the water quality VEC study includes the Ohio River mainstem, lands along either bank within the approximate 500-year floodplain, and terraces located adjacent to and above the floodplain. The temporal boundaries for most topics encompass from 1920 to 2070, with the earlier date approximating the initiation of the Corps' lock and dam construction activities on the Ohio River, and the latter date approximating the end of the 60-year planning horizon encompassed by the ORMSS.

Water quality was identified in early study planning by the Corps and the IWG as an important topical issue to be addressed. This identification was confirmed via the number of comments and specific concerns expressed in 12 public scoping meetings. A total of 21 direct comments on water quality were received, along with an additional 45 comments that have implications for water quality. These comments have been addressed herein.

Several federal laws are related to Ohio River water quality. The primary one is the CWA; others include the SDWA, various Water Resources Development Acts, site remediation laws, and the Oil Pollution Act. Regulatory and other permit programs exist under the auspices of the CWA and the Rivers and Harbor Act. ORSANCO, formed in 1948, has played a major role in the implementation of the requirements of the CWA, including interstate coordination, adoption of water quality standards for the river, promotion of the construction and operation of municipal wastewater treatment plants, and water quality and aquatic ecological monitoring.

3.13.1 Describing the Affected Environment

Six indicators for describing the affected environment and evaluating the environmental sustainability (ES) of the water quality VEC were utilized in this CEA study. They included: 1) several water quality parameters (e.g., DO, pH, fecal coliforms, turbidity, total suspended solids, and nutrients); 2) the level of conformance with state and federal water quality standards, including attainment of permissible use designations; 3) implementation of an appropriate TMDL program; 4) the effectiveness of specific point source control and nonpoint source control programs; 5) the effectiveness of spill response, monitoring programs, and related precautionary measures; and 6) the overall ability to sustain diverse, healthy populations of aquatic organisms. In assembling information on these indicators, along with related biological indicators such as algae and aquatic macroinvertebrates, approximately 70 scientific publications and reports were reviewed.

Limited information prior to 1920 indicated that water quality probably declined between 1820 and the 1940s due to population growth and industrial development throughout the Ohio River basin. Historical lows in DO occurred downstream of Pittsburgh, Cincinnati, and Louisville in the late 1960s to mid 1970s. New municipal wastewater treatment plants built by many cities along the mainstem from the 1970s to the 1990s contributed to increases in DO above the standard of 5.0 mg/l, and today, the entire 981-mile mainstem length is routinely in compliance with the DO standard. Operational practices at several navigation dams with hydropower have also enhanced DO levels in the mainstem.

Chronic AMD from high-sulfur bituminous coal mines has historically caused lowered pH readings for mainstem waters. During the 1960s and 1970s, AMD pollution was reduced by mandatory treatment of active coal mine effluents, and by the 1980s the pH standards (between 6.0 and 9.0) were achieved at all mainstem monitoring stations. However, a potential AMD concern has recently been identified. It relates to numerous mining company bankruptcies that have led to large underground mining complexes that have been abandoned and are now being flooded. Without intervention, these abandoned mines are predicted to again discharge AMD to upper Ohio River tributaries. Such discharges would disrupt the sustainability of upper mainstem water quality and related aquatic resources such as fish populations.

Total coliform bacterial data for the mainstem are available from the 1939-1943 time period, with the counts exceeding 20,000/100 mL for 31 to 61% of the time at the utilized monitoring stations. From the 1940s to the 1960s, implementation of primary treatment plants for municipalities along the river caused dramatic declines in coliform bacterial counts in both the upper and lower reaches of the river. Such declines were aided in the lower river by the greater available assimilative capacities. Completion of secondary treatment plants in the 1970s through the early 1990s still further reduced coliform levels. However, the current water quality standard is 200/100mL as a monthly geometric mean, and exceedances still occur downstream of major urban areas such as Pittsburgh, Wheeling, Huntington, Cincinnati, Louisville, and Evansville. Discharges of urban runoff via CSO have been identified as contributors to the exceedances of the standard; in fact, 52 CSO systems contribute discharges to the river. Such contributions may worsen as a result of further urban population growth and changes in land use patterns; however, continued implementation of Phases 1 and 2 of the NPDES stormwater permit program will provide further controls of coliform organisms.

The turbidity and total suspended solids (TSS) of the mainstem waters are influenced by river flows and velocities (particularly during flooding conditions), erosional characteristics of the native soils, dredging activities, sand and gravel extraction operations, clearing of lands, construction related to new urban or industrial developments, and discharges of treated wastewaters and untreated urban and rural runoff. Flood-induced turbidity and TSS have declined to some extent due to sediment retention in the pools upstream of the locks and dams. Further, there are no specific water quality standards for turbidity and TSS.

The historical information base for nitrogen and phosphorus in the Ohio River is not robust. However, a decreasing trend in ammonia nitrogen and total nitrogen was noted in the 1977 to 1987 time period. This trend can be attributed to improved wastewater treatment levels and some implementation of BMPs for control of both urban and rural runoff. Of particular importance are BMPs for rural (agricultural) runoff. Water quality criteria (not standards) for human health are 10 mg/L for nitrite plus nitrate nitrogen, and 1.0 mg/L for nitrite nitrogen. Monitoring data from the lower mainstem in 2000 indicated that the nitrogen concentrations were well below the standards. While these standards are not being exceeded, there is a concern related to the Ohio River basin's contribution to the nitrogen loading entering the Gulf of Mexico, and the associated depressed DO levels (hypoxia problems) in the northern Gulf area. It has been estimated that the Ohio River basin contributes 44% of the nitrogen loading basic to these problems.

Regarding total phosphorus in mainstem water, ORSANCO has not yet established a standard. Switches to phosphate-free detergents in the early 1980s led to a decreasing trend in the phosphorus concentrations in the Ohio River. Recent measurements have typically been below 1.0 mg/L (the recommended USEPA standard), except downstream from Markland L/D, where agricultural chemicals may have contributed to higher concentrations. Agricultural chemicals are a major contributor to current phosphorus loadings in the river, along with wastewater discharges from municipalities and industries.

The TMDL refers to the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Consequently, a TMDL represents the sum of allowable loads of a single pollutant from all contributing point, nonpoint, and natural

sources. To date, TMDLs for dioxin and polychlorinated biphenyls (PCBs) have been established for specific segments of the Ohio River. These TMDLs are a result of the two contaminants being found in fish tissue, and the resultant issuance of consumption advisories for certain fish species. Consideration is currently being given to the future development of a TMDL for *E. coli*.

The natural bottom substrate of the Ohio River is mainly sand, gravel, or clay overlain, especially in near shore or other sheltered areas, with silt and/or organic detritus. These overlying sediments are generally mobile and dynamic, and storm events may lead to displacement and subsequent redeposition of various proportions of the materials. Further, such sediments are natural "sinks" for many toxic and persistent pollutants. Significant heavy metal contamination of sediments has resulted from coal mine drainage with inflows of iron and manganese and industrial activity, particularly the iron and steel industry of the upper Ohio River valley. These legacy-contaminated sediments may continue to adversely affect overlying waters and food chains for years. In addition, contaminated sediments have also been found in the middle river area between and below metropolitan areas. One concern related to legacy sediments is that the contaminants can be remobilized under certain flow and low pH conditions. Further, such dissolution of the contaminants could lead to toxicities to nearby aquatic organisms. However, only a few localized studies of sediment quality and related consequences have been conducted, thus the information base is not robust. In this regard, a systematic study of sediment quality, contaminant remobilization tendencies, and potential consequences on aquatic resources is needed for the entirety of the Ohio River mainstem. Finally, there is some evidence of natural recovery associated with legacy-contaminated sediments; for example, there has been a re-emergence of burrowing mayflies in the upper Ohio River in the last decade.

Biological surveys of fishes, algae, and macroinvertebrates have been conducted by ORSANCO since 1957. Such surveys provide evidence of the composite effects of water quality conditions on aquatic ecological resources. For example, improvements in fish diversity have been noted since the late 1960s for the middle and upper river segments, with such improvements attributed to increased DO concentrations and pH levels, and reductions in the concentrations of chemical toxicants (the accompanying discussion of fish resources in Chapter 4 provides more specific information).

Algae can occur in attached and free-floating (planktonic) forms, with diatoms often dominating the planktonic community. As such, they represent food sources that are foundational components of the aquatic ecosystem. Plankton (phytoplankton) studies of the Ohio River have been conducted at various times over five decades (1957 to 1960, 1974 to 1975, 1990s, and 2002). Depressed concentrations of phytoplankton were found in the AMD-polluted upper river in the 1957 to 1960 studies, and no blue-green algae, which are species sensitive to acid conditions, were found in the same area in the 1974-75 studies. The navigation system was also found to influence the longitudinal distribution of phytoplankton in the river. For example, several unpublished studies from 1976 to 1991 found that phytoplankton concentrations in near surface samples were elevated in the downstream sections of navigation pools where velocities are low; in contrast, such concentrations were reduced downstream of the locks and dams.

In a plankton study conducted during the 1990s, in the reach between Cincinnati and Evansville, it was determined that the Ohio River supports diverse, substantial phytoplankton communities. By this time period, the composite water quality in the river

had been markedly improved due to municipal and industrial wastewater treatment plants. Further, it was found that temperature increases enhanced phytoplankton densities; with flow velocity increases causing decreases in densities. A collaborative and comprehensive study conducted from 1999 to 2002 monitored phytoplankton and chlorophyll at 10 water intakes along the river (from mile 4.5 to 935.5). It was found that both phytoplankton and chlorophyll increased in the downstream direction, and this generally coincides with improved water quality conditions. Further, it was determined that the phytoplankton community is both dynamic and complex, containing over 100 genera.

Benthic macroinvertebrate communities are good indicators of localized water quality conditions, and they also serve as a primary food source for many fish species. Macroinvertebrate studies of the Ohio River have also been conducted at various times over five decades (1957 to 1960, 1963 to 1967, and at various other times to 2002). Specific types and quantities of benthic organisms have been found to be associated with certain types of substrates; for example, silt bottoms support larger numbers than do sand or sand and silt bottoms. Composite condition scores determined in 1967 for aquatic macroinvertebrates indicated improvements in the scores from the upper (scores of 12 to 45) to the middle (35 to 72) to the lower (55 to 83) segments of the river. In 2002, comparative composite condition scores were developed for the upper segment only, with the scores being higher (39 to 59) than those in 1967 (12 to 45). In general, these findings support a positive relationship between improved water quality conditions and more robust benthic macroinvertebrate communities. Because the information base for macroinvertebrates is robust, the possibility exists for the scientifically based selection of "signature species" for inclusion in longer-term monitoring programs for the Ohio River mainstem.

The designated uses of the Ohio River include support of warm water aquatic life, public water supply, fish consumption, and contact recreation. ORSANCO has developed assessment criteria for three categories for each of the four uses; the categories are "fully supporting", "partially supporting", and "not supporting." Water quality data and standards, along with measurements of fish communities and fish consumption advisories form the bases for the criteria (information on fish communities is in Chapter 4 and consumption advisories are addressed in Chapter 8, "Health and Safety"). Regarding support of aquatic life, in 1998-99, only 66.1 miles of the 981-mile length of the Ohio River were "not fully supporting" this use (915 miles were in the "fully supporting" category); in 2000-01, only 7 miles were "not fully supporting." For the public water supply use, only 4.4 miles were "not fully supporting" in 1998-99, and 10.5 miles were "not fully supporting" in 2000-01. In both 1998-99 and 2000-01, all 981 miles were designated at "not fully supporting" fish consumption (this designation is based on the criteria that "no consumption" advisories are in effect for all commonly consumed species, or that restricted fish consumption advisories are in effect). Finally, in 1998-99, 355.4 miles of the river were "not fully supporting" contact recreation use; and in 2000-01, the number dropped to 176.7 miles. Bacterial concentrations at six recreational monitoring stations are the primary cause of the "not fully supporting" designations for contact recreation. In the future, the "not fully supporting" designations should decline with further treatment of wastewater discharges, pollution prevention and control efforts, and compliance with CSO regulations.

3.13.2 Assessing the Cumulative Effects of Past, Present, and Future Actions

Multiple past and present actions have affected the water and sediment quality of the mainstem, and multiple future actions are also anticipated to contribute to the overall CEs on the water quality VEC. The systematic evaluation of 87 types of reasonably foreseeable future actions (RFFAs) indicated that seven were ranked as having "high importance" relative to CEs, and 20 were designated as having "medium importance." The importance ratings reflect the composite consideration of the future time period of occurrence, likelihood of occurrence, potential for multiple locations along the river, the spatial and temporal extent of the anticipated effects, the level of knowledge about the effects, the relative contribution to the CEs, and the possibilities for cost-effectively mitigating the negative consequences. These 27 RFFAs have been characterized by their common effects into those causing turbidity and sedimentation (T/S) during construction and/or operation; those contributing to point source (PS) pollution due to discharges of organics, nutrients, thermal content, bacteria, and/or toxic chemicals; those contributing to nonpoint source pollution (NPS) due to the bacterial, nutrient, or pesticide content of urban or agricultural runoff; and those contributing to pollution reduction (PR) via environmental restoration projects, regulatory controls, or educational efforts. Examples of how RFFAs contribute to both adverse and beneficial effects on water quality are included earlier in this chapter. Further, it should be noted that the 27 RFFAs reflect continuations of actions initiated in the past along the Ohio River mainstem.

The high importance actions that contribute to adverse T/S effects include channel dredging/dredged material disposal and instream sand and gravel mining. Medium importance actions include L/D operation and maintenance, port development and maintenance dredging, fleeting areas and barge storage, terminals, multi-modal sites, increased navigation traffic, and marine development and operation.

The high importance actions that contribute to adverse PS pollution effects include instream sand and gravel mining, coal utilities, other coal industries, and industrial users (excluding coal-related). Medium importance actions include fleeting areas and barge storage, accidents/spills, industrial wastewater discharges, and stormwater discharges (from CSOs). Regarding adverse NPS pollution effects, high importance actions include channel dredging/dredged materials disposal, coal utilities, other coal utilities, and industrial users (excluding coal-related users). Medium importance actions related to adverse NPS pollution effects include L/D operation and maintenance, dry dams and other projects off the mainstem, floodplain sand and gravel mining, industrial development in the floodplain, marina development and operation, agriculture, and stormwater discharges.

PR is expected to result in beneficial effects on water and sediment quality. The high importance actions (or programs) that contribute to such effects include more stringent quality standards for environmental media, and pollutant source control. Medium importance actions and programs include ecological restoration, Phases 1 and 2 of the NPDES stormwater permit program, the TMDL program, effluent trading, control of agricultural discharges, and environmental awareness education.

ES has been used as the "ultimate test" whereby the significance of CEs from multiple actions on water quality can be qualitatively evaluated. The AES involved "connecting" the four common effects from the 27 high and medium importance RFFAs to

the six indicators of ES used to describe the historical situation, trends, and current conditions of the water quality VEC. For purposes of this analysis, the indicators were divided into three tiers and re-grouped. The first tier included "scientific measures of quality" such as water quality parameters and conformance with standards. The second tier encompassed "positive actions related to source control" that included point source control and nonpoint source control programs, TMDL implementation, spill response, monitoring programs, and related precautionary measures. The third tier included two "composite indicators of aquatic ecosystem sustainability" developed from several of the indicators; they were attainment of permissible use designations, and sustainment of diverse, healthy populations of aquatic organisms. The qualitative discussion of the connections was based on some quantitative data, fundamental scientific information, and professional judgment. Three categories of ES were defined as follows:

- Not sustainable -- the composite conditions for the selected indicators do not reflect conditions that would facilitate attainment of permissible use designations, nor would they sustain diverse populations of aquatic organisms.

- Marginally sustainable -- the composite conditions for the selected indicators are such that the attainment of permissible use designations is accomplished for the majority, but not all, of the river miles in the mainstem, and diverse populations of aquatic organisms are occurring along the majority of the river; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences.

- Sustainable -- the composite conditions for the selected indicators are such that the attainment of permissible use designations is accomplished for essentially all of the river miles in the mainstem, and diverse populations of aquatic organisms are occurring along the majority of the river; further, the conditions of the indicators exceed regulatory thresholds and various governmental programs are in place to control point and nonpoint pollution sources and to emphasize pollution reduction.

Based upon the above-described affected environmental conditions, the multiple actions and effects, the tiers of indicators, and the ES categories, the ES of the water quality of the mainstem of the Ohio River can be characterized and depicted in **Figure 3-4** as follows:

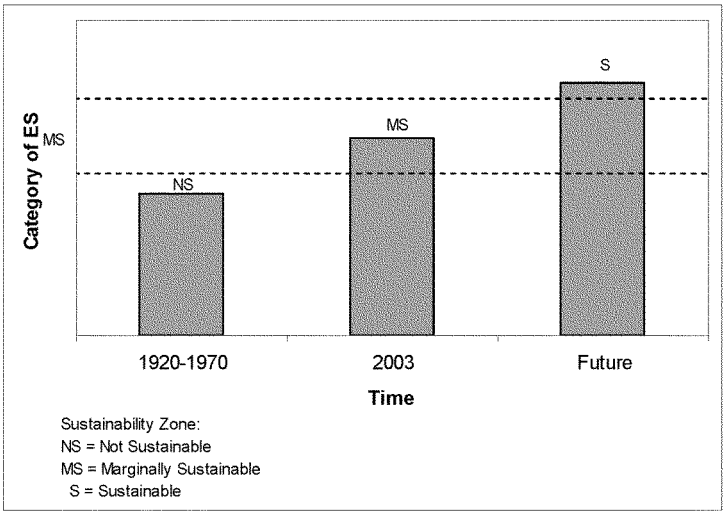
- In the time period prior to 1920, and continuing up to about 1970, the water quality of the mainstem was in a degraded state characterized by low DO concentrations, low pH levels in the upper river, high bacterial contamination, high nitrogen concentrations, and remobilization of potentially toxic chemicals that had become associated with river sediments. Essentially no pollution reduction, control programs, or regulatory programs, were in place during this period. Further, declines in the diversity and health of fish communities in the mainstem also were experienced (see Chapter 4). Accordingly, the ES of the water quality VEC was classified as "not sustainable." Primary contributors to these conditions were the largely untreated and uncontrolled point and nonpoint pollutant discharges from growing municipalities, mining, and various types of industries and land uses along the river.

- Due to the programs of ORSANCO, and the requirements of the FWPCA (and the amended CWA), water quality of the Ohio River has shown a steady improvement in recent decades. For example, DO concentrations are typically above the 5.0 mg/L standard, pH levels are between the 6.0 to 9.0 standard, and nitrogen concentrations meet current water quality criteria. However, bacterial contamination primarily associated with NPS pollution is still problematic downstream of major urban areas. Further, legacy "contaminated sediments" are a concern in the upper river along with fish consumption advisories throughout the mainstem. In contrast, the results of algae (plankton) and aquatic macroinvertebrate biological surveys in the five most recent decades have demonstrated steady improvements in these aquatic ecological resources, with the improvements paralleling water quality improvements. Regarding the attainment of permissible use designations, as of 2003, 779 of 981 miles (~80%) of the mainstem are "fully supporting" aquatic life, and 949 miles (~97%) are "fully supporting" public water supply use. None of the mainstem was "fully supporting" fish consumption due to restricted or no consumption advisories along its total length. For contact recreation, 269 miles (~27%) are "fully supporting" this use, with major impairment continuing from combined sewer systems in urban areas. Overall, implementation of NPDES permit programs for municipalities, industries, and stormwater has led to the reduction of discharges into the mainstem. Initiatives for increasing the use of BMPs have also been established. Also, information from the fish resources chapter has indicated that the diversity and health of fish communities along the mainstem has considerably improved from the 1920 to 1970 period. Accordingly, at this time (2004), although there are many positive signs, the ES of the water quality VEC is classified as "marginally sustainable." The primary concerns are associated with bacterial contamination and chemical remobilization from legacy-contaminated sediments.

- Regarding the future, it is expected that the water quality of the Ohio River mainstem will further improve as a result of the continuation of source control and other pollution reduction programs, and implementation of restoration and remediation efforts. Therefore, it is anticipated that the ES of the water quality VEC will achieve a "sustainable" condition. However, this characterization should not bring complacency; rather, vigilant efforts are still needed to continue effective water quality and aquatic ecological monitoring and management efforts. In this regard, it may be desirable to plan and implement source monitoring programs for selected RFFAs (actions) considered of high importance relative to cumulative effects. Further, special surveys for legacy-contaminated sediments are needed along with site-targeted efforts to reduce bacterial effluents from CSOs. Furthermore, several actions are expected to be beneficial to the water quality resource in the future. For example, adverse impacts related to barge operation (e.g., queuing, dispersed traffic) will be alleviated to some extent 1) through implementation of nonstructural navigation improvements and 2) through technological improvements related to communications and more environmentally-advanced barge design. Activities that support commercial navigation (e.g., port development and maintenance dredging) will continue to be scrutinized by both regulatory agencies and NGOs and may be more strictly regulated. Land disposal of in-stream dredged materials, for example, may become more common. Some development activity may revive or renovate underused urban space or industrial brownfields areas, with possible long-term water quality benefits related to surface

and groundwater clean up. Much development activity, however, will involve conversion of existing floodplain lands (e.g., farmland, riparian woods, and wetlands) that now afford habitat protection, open space, and ecosystem values. Once converted, such lands are unlikely to revert to their former more natural states. Increasing emphasis on pollution prevention, erosion control BMPs, and implementation of the Phase 1 and 2 NPDES programs could counteract some adverse impacts, particularly in more urban areas. In general, several regulatory initiatives in recent years, including TMDL development, the national CSO policy, and Phase 1 and 2 programs should measurably improve water and sediment quality, but, at this time, it is not possible to predict the magnitudes of their beneficial effects.

FIGURE 3-4.
ES of Water Quality



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Chapter 4
FISH

4.1 TABLE OF CONTENTS

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4.2 IMPORTANCE OF FISH AS CUMULATIVE EFFECTS INDICATORS

This chapter considers how cumulative effects (CE) of human use of the Ohio River have influenced fish communities and what impacts on fish may be anticipated in the foreseeable future. Fish of the Ohio River represent a highly visible and important environmental component. Fish also are excellent indicators of cumulative effects and environmental sustainability for several reasons:

- Their multiyear life spans and mobility facilitate interpretation of long-term effects and larger-scale habitat conditions.
- Fish communities include a wide range of species, trophic (feeding) levels, and reproductive conditions that can reflect varying degrees of environmental change.

- Some fish species are very sensitive to chemical and physical changes that may be caused by pollutants, changes in flow patterns, and other factors.
- Fish are easier to collect and identify and more information is available on their life histories than for small invertebrates.
- Fish are of interest and concern to society due to their potential for food and sport.

Fishes of the Ohio River interact with several other Valued Environmental Components (VECs) including water quality, mussels, riparian/floodplain ecological resources, recreation, land use, and human health. Because of their importance to humans and their diversity, they have been studied more extensively than any other biotic group in the Ohio River.

4.3 OBJECTIVES AND SCOPE OF THE FISH STUDY

4.3.1 Objectives

This chapter assesses the system-wide cumulative impacts on fish of all likely major navigation improvements along the mainstem of the Ohio River during the planning period from 2000 to 2070. Impacts directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the U.S. Army Corps of Engineers (Corps) and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFAs. These future actions include the major navigation improvements identified in this study, other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies, actions by non-governmental entities, and predictions of general economic expansion and development as well as regulatory changes.

The results of the Cumulative Effects Assessment (CEA) will lead to further consideration of:

1) the significance of the impacts of RFFAs on affected resources
2) the degree to which proposed navigation improvements contribute to those impacts and
3) what constitutes sustainable fish communities in the Ohio River mainstem.

4.3.2 Geographic Scope

The geographic focus for impacts on fish includes the Ohio River mainstem, which is most directly impacted by operation and maintenance of the navigation system, and also includes lands along either bank of the Ohio River lying "between the bluffs." This "floodplain zone" is defined as the meander channel of the Ohio River and includes the 100- and 500-year floodplains as well as terraces of level land lying above these flood zones. Floodplain lands are considered in this assessment because fish communities are affected by siltation, runoff, and contaminants associated with construction, industry, agriculture, and other land-based activities. The contribution of tributaries to recruitment of mainstem fish populations is also considered.

4.3.3 Time Frame

The established time frame for this project is 1920 to 2070. The earlier date approximates the initiation of the Corps' long-term 20th century lock and dam (L&D) construction activities on the Ohio River while the latter date approximates the end of the 60-year planning horizon encompassed by the Ohio River Mainstem Systems Study (ORMSS). Discussion of impacts on fish, however, includes consideration of the condition of fish communities before 1920. Understanding pre-1920 conditions is important in determining how lock and dam construction/operation and other human activities have influenced fish communities.

4.4 ISSUES FROM SCOPING

A series of 12 public scoping meetings was held during Summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. A more detailed discussion of the scoping meetings is presented in Exhibits A and B of this report.

The meetings were attended by 185 persons and over 200 verbal comments were recorded from the question and answer sessions. These comments accounted for the large majority of input. Additional comments were obtained from 19 questionnaires and several letters that were submitted. Fish and fishing were frequently mentioned during the meetings. Comments that directly and indirectly addressed fish and fishing are presented in **Table 4-1**.

TABLE 4-1
Comments from Public Scoping Meetings

Direct Comments Related to Fish and Fishing	Relevance to Fish and Fishing	Total
Increased spills and accidents potentially affecting aquatic life and impairing water quality (WQ)	Lowering of WQ & damage to fish and other aquatic resources	1
Possibility of implementing mechanical aeration in mainstem pools	Need for sufficient oxygen levels for fish and other aquatic resources	1
Importance of continued water quality improvements as a high priority	Need for WQ improvements to benefit fish and other aquatic resources	1
Mouths of tributaries silted in, impairing fish habitat, limiting access, and damaging property	Damage/elimination of habitat for fish and other aquatic resources	5
Damage destruction of mussel beds and fish spawning areas	Reduction in mussels and fish	4
Impaired water quality and bioaccumulation in fish tissue of harmful substances stirred up by dredging	Uptake of toxic substances in the food web	2
Habitat damage caused by Corps permitted commercial sand and gravel operations	Reduction in fish and other aquatic resources	1
Effects on fishing caused by water level fluctuations	Unpredictability of fishing habitat	3
Under-representing of fishermen in ORMSS scoping process	Concerns that fishing-related issues will not be adequately addressed	1
Increase in barge loading/unloading facilities	Decreased availability of shore-based	1

Direct Comments Related to Fish and Fishing	Relevance to Fish and Fishing	Total
limiting fishing access from shore	fishing areas	
Need for fish habitat improvements, including fish passage around locks and dams	Need to overcome potential migration barriers	2
USACE role when fish kills occur	Clarification of agencies for notification and assessment of fines	1
Effects related to three crayfish, two fish, and seven mussel species in Illinois	Concern for species of special interest in the lower Ohio River	2
Need to prevent distribution of exotic/invasive plants and animals through USACE actions	Concern for impacts on native fish and other aquatic resources	1
Other Comments with Implications for Fish and Fishing		
Need for ongoing coordination and cooperation with concerned agencies and groups	Importance of working together to achieve WQ goals that support fish and other aquatic resources	3
Development of ongoing program to reevaluate cumulative effects every 5 years	Need for continual assessment of fish and other environmental components	1
Importance of including commercial dredging and associated permitting process in CEA	Dredging causes turbidity and can damage fish habitats	2
Need to consider 404 application approvals and resultant actions as direct USACE actions	Concern for potential impacts on fish habitat	1
Importance of coordination with resource agencies to determine baseline conditions	Concern that all relevant data is used	2
Cumulative effect of discharges on river may offset water quality improvements	Failure to attain WQ standards and potential damage to fish and other aquatic resources	4
Challenges to water quality presented by CSOs (combined sewer overflows) and SSOs (storm sewer overflows)	Failure to attain WQ standards and potential damage to fish and other aquatic resources	2
High levels of mercury, arsenic, fecal coliform bacteria and agrichemicals in surface water	Failure to attain WQ standards and potential damage to fish and other aquatic resources	1
Need for more stringent discharge permitting procedures or moratorium on permits	Failure to attain WQ standards and potential damage to fish and other aquatic resources	2
Need to improve sediment and erosion control from public and private developments	Potential turbidity and sedimentation harming fish and other aquatic resources	1
Need for long-term plan to address silt removal and prevent future sedimentation	Potential turbidity and sedimentation harming fish and other aquatic resources	1
Possible use of dredge spoils to improve riparian or island habitat or for upland filling	Creation of new habitat for fish and other aquatic resources	2
Bank undercutting and failure caused by increased barge traffic, queuing and wave action	Potential erosion and sedimentation lowering WQ and harming fish and other aquatic resources	7
Loss of significant farmland to urban development along river corridor	Increased stormwater runoff harming fish and other aquatic resources	3
Loss of green space and wildlife habitat with development of marina facilities	Increased runoff & potential pollution from marinas harming fish and other aquatic resources	5
Development of floodplains and wetlands resulting in increased runoff and habitat loss	Increased runoff and loss of wetland filtering capacity harming fish and other aquatic resources	4
Need to develop comprehensive plans for development along river	Importance of nonpoint pollution and cumulative effects on fish and other aquatic resources	3
Need for coordination with community floodplain coordinators along river	Could benefit fish and other aquatic resources	1

Direct Comments Related to Fish and Fishing	Relevance to Fish and Fishing	Total
Loss of unique, sensitive species due to water quality problems and habitat modifications	Reductions in aquatic life	2
Potential instability of Ohio River islands and futility of creating islands wildlife refuge	Related to island habitat for fish and other aquatic resources	2

Comments from public scoping meetings were reviewed as the list of RFFAs was developed for this assessment. In some manner, almost all comments in **Table 4-1** are encompassed by the RFFA list. Later in this chapter, the CE of RFFAs affecting fish are grouped and discussed according to their impacts which may cause: 1) habitat changes, 2) changes in disturbance regimes, 3) changes in hydrological patterns, 4) effects on ecological services, and 5) changes related to populations. The comments presented in **Table 4-1** are connected to these potential impacts. For example, the last comment in the table above, which concerns islands, is directly related to habitat and changes in disturbance regimes that can affect localized populations of fish. Almost all the public comments can be linked to one or more of the five impacts mentioned above. These impacts are discussed in more detail in the "Relevant Actions" and "Cumulative Effects and Environmental Sustainability" sections of this chapter.

Further, because of the interdisciplinary nature of CEA, public comments frequently are related to more than one VEC. Several comments applicable to fish, therefore, also apply to water quality, mussels, and /or Riparian/Floodplain Resources (RFR) and thus appear in the corresponding public comments tables in those chapters.

4.5 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY

Indicators of Environmental Sustainability (ES), which vary by VEC, generally provide benchmarks for measuring CE on a given resource or VEC. The primary uses of indicators are to characterize the current status of a resource and to track or predict significant changes to the resource. It is desirable to select indicators that can be supported by data that are measurable and relatively straightforward to collect. Further, if an indicator is to be accepted and used to guide policy, the data upon which indicators are based must be available to a wide range of interested parties (NRC 2000).

ES indicators selected for fish encompass the basic essentials for diverse communities of fish to thrive and reproduce in the Ohio River. Key indicators, therefore, include:

- composition of fish communities, including numbers of intolerant and nonnative species, abundance, and diversity
- amount of habitat with stable substrates, adequate depths, suitable currents, and sufficient food supplies
- reproductive viability as measured by amount of spawning habitat, genetic connectivity, and numbers of gravid females, and larval individuals
- percent of population with abnormalities such as parasites, tumors, ulcers, and fin erosion
- water quality measurements such as levels of Dissolved Oxygen (DO), and pH and
- level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic.

The entire suite of indicators may be essential to adequately characterize and track Ohio River fish communities. In contrast to several other VECs, long-term data are available for many indicators of fish sustainability. Data to assess the selected indicators are included in studies conducted by the Corps, USFWS, ORSANCO, universities, electric utilities, and others. Ohio River fish communities are discussed in further detail in the section titled "Past to Current Baseline Conditions."

4.6 LAWS, REGULATIONS, ORDINANCES, AND PROGRAMS

As Chapter 3, "Water Quality," details, a pivotal regulatory event for the Ohio River's water quality, fish, and other aquatic ecological resources was the signing of an interstate compact in 1948 that created ORSANCO. The principal mission of ORSANCO was to abate existing pollution and control future pollution of waters in the Ohio River basin (ORSANCO 1998). The marked improvements to Ohio River water quality made through ORSANCO and other governmental regulations and programs during the past half-century were key to reversing the declining state of Ohio River fishes in the mid-20th century.

Table 4-2 illustrates the spectrum of regulations and established programs related to fish of the Ohio River. In many cases, protection of the fish community and fishery resources is a consequence of other environmental objectives, such as improving water quality or protecting wetlands.

TABLE 4-2
Laws, Regulations, Ordinances, And Programs Relevant to Fish and Fishery Resources

Law/Program	Key Components	Relevance to Fish
Clean Water Act (CWA) (U.S. Environmental Protection Agency)	• Section 402 establishes National Pollution Discharge Elimination System (NPDES) for regulating pollution discharges into U.S. waters. • Section 316(b) requires cooling water intake structures to reflect best available technology to minimize adverse environmental effects. • Section 401 of CWA requires applicants proposing activity, which may result in discharge to U.S. waters, to obtain certification of compliance with state water quality standards. This section is administered by each individual state. • Gives USEPA authority to implement pollution control programs • Requires establishment of water quality standards • Recognizes need to address nonpoint source pollution	Protects fish within general context of water quality improvements and minimization of impacts from construction or other activities within state waters.

Law/Program	Key Components	Relevance to Fish
National Environmental Policy Act (NEPA) (Council on Environmental Quality and other resource agencies)	• Requires preparation of environmental impact statements for new construction projects by private and governmental agencies.	Includes water quality & habitat impacts of new projects along the Ohio River such as power plants, Corps projects and riverfront developments.
Water Resources Development Act (WRDA) (U.S. Army Corps of Engineers)	• Authorizes Corps' port development, navigation, flood control and erosion control projects through the 1986 act and subsequent amendments	Contains provisions for environmental assessment and mitigation that can affect fish
Oil Pollution Act (U.S. Environmental Protection Agency)	• Strengthened EPA's ability to prevent & respond to catastrophic oil spills	Protects fish and other aquatic resources from pollution & damage from oil spills
Emergency Wetlands Resources Act (US Fish & Wildlife Service)	• Authorizes purchase of wetlands from Land and Water Conservation fund • Requires states to includes wetlands in Comprehensive Outdoor Recreation Plans • Provides funding for the Migratory Bird Conservation Fund	Benefits fish habitat by encouraging federal-state cooperation in wetlands protection and outlines funding mechanisms
Endangered Species Act (USFWS)	• Authorizes determination & listing of threatened & endangered species • Prohibits unauthorized taking, possession, sale & transport of endangered species • Provides for land acquisition to protect endangered species	Establishes framework for protection of threatened & endangered species that are components of the aquatic ecosystem upon which fish rely
Fish & Wildlife Act (USFWS)	• Section 7(a) requires (U.S. Department of Interior) (USDI) to take steps required for management & protection of fish & wildlife resources through research, acquisition of land & water & other means.	Establishes a comprehensive national fish & wildlife policy applicable to fish and other aquatic and riparian resources
Fish & Wildlife Coordination Act (USFWS)	• Requires that whenever water bodies are modified by federal agency, that agency first shall consult with the USFWS and with appropriate state agencies with a view toward wildlife conservation	Provides for equal consideration and coordination of fish and wildlife conservation with other aspects of water resources development
National Wildlife Refuge System Administration Act & National Wildlife Refuge System Improvement Act (USFWS)	• Provide guidance for management and public use of refuge system, including development of comprehensive conservation plan for each refuge	Guide management & public use of Ohio River Islands National Wildlife Refuge, including fish habitat
National Invasive Species Act (US Dept. of Transportation and Aquatic Nuisance Species Task Force)	• Requires all vessels operating in US waters that are equipped with ballast tanks to comply with guidelines designed to prevent and reduce the dispersal of aquatic nuisance species	Helps reduce the further introduction and dispersal of invasive species that can disrupt aquatic ecosystems

Law/Program	Key Components	Relevance to Fish
Farm Security and Rural Investment Act of 2002 (aka Farm Bill) (USDA Natural Resources Conservation Service)	• Includes various incentive programs to promote installation of riparian buffers. • Swampbuster provisions withhold certain USDA benefits from farmers who convert or modify wetlands • Offers opportunities for wetlands mitigation	Helps improve and/or preserve environmental functions & value of riparian areas in the Ohio River floodplain, which also benefit fish and other aquatic resources
Corps Permitting Statutes (U.S. Army Corps of Engineers)	• Section 10 of Rivers and Harbors Act (1899) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. • Section 404 of the CWA authorizes the Corps to issue permits for the discharge of dredged or fill material into the waters of the United States	Permits require assessment of impacts on water quality, fish and other aquatic resources and mandate mitigation of adverse impacts
Small Navigation Projects (U.S. Army Corps of Engineers)	• Section 107 of Rivers and Harbor Act (1960) authorizes Corps to develop and construct small navigation projects for harbor protection.	Includes impacts of such actions on water quality, fish and other aquatic resources
State Water Quality Certification (Appropriate state or interstate pollution control agencies)	• Section 401 of the CWA requires certification from state or interstate water control agencies that a project is in compliance with established effluent limits and water quality standards.	Provides opportunity for state or interstate scrutiny of such actions on fish and other aquatic resources
Site Remediation Statutes (U.S. Environmental Protection Agency)	• Includes CERCLA, RCRA, SARA and related state programs that focus on cleanup and restoration of contaminated sites.	Potentially reduces groundwater and soil pollution sources which may adversely impact fish and other aquatic resources in the Ohio River
TMDL Program (U.S. Environmental Protection Agency)	• Increasingly important section (§303) of CWA; regulates maximum pollutant load a water body can receive and still attain water quality standards.	Presents a more holistic option to water quality management than traditional approaches with potential benefits for fish and other aquatic resources
Phase 1 & 2 NPDES Program (U.S. Environmental Protection Agency)	• Also developed within the CWA, requires municipalities and certain industrial and construction sites to adopt BMPs to control nonpoint sources of pollution.	Should reduce pollution characteristics of stormwater discharges from urban and industrial zones that may adversely affect fish and other aquatic resources in the Ohio River
National CSO Control Policy (U.S. Environmental Protection Agency)	• Published by USEPA, calls for communities to implement long-term plan for combined sewer overflows (CSOs) to comply with the CWA. • Administered through each state's NPDES permit program.	Should reduce pollution from major urban sources with potential benefits for fish and other aquatic resources

Law/Program	Key Components	Relevance to Fish
Executive Order 11988, Floodplain Management & Executive Order 11990 (Both in 1977) (Executive Branch)	• Prevents federal agencies from contributing to the adverse impacts of floodplain development & modification	Restricts federal development in Ohio River floodplain wherever there are practicable alternatives with potential benefits for fish and other aquatic and riparian resources
Executive Order 13112, Invasive Species (1999) (Multi-agency National Invasive Species Council)	• Requires federal agencies to prevent the introduction of invasive species and provide for their control and to minimize their economic, ecological and human health impacts	Helps to maintain and/or restore the ecological integrity of aquatic and riparian ecosystems
Spill Response (U.S. Coast Guard & ORSANCO)	• Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the CWA.	Minimizes adverse impacts of spills and discharges on fish and other aquatic resources and on water quality
ORSANCO Monitoring (ORSANCO)	• Encompasses ongoing water quality and aquatic ecology monitoring programs by ORSANCO.	Helps track trends in water quality and biological communities and provides database that can inform environmental decision-making
State Fishing Regulations (State resource agencies & Ohio River Fisheries Management Team)	• Establish regulations that consider fish habitat and reproduction. Ohio River state resource agencies are developing an Ohio River Fisheries Management Team to standardize fishing regulations for the entire river.	Has potential to enhance environmental sustainability of Ohio River fish communities through long-term collaborative fisheries management efforts.

4.7 PAST TO CURRENT BASELINE CONDITIONS

The Ohio River, as part of the Mississippi drainage, has provided continuous habitat for fishes for over 200 million years. Because large-scale geologic events have shaped the Mississippi drainage, its fish community is exceptionally rich in species and represents the center for adaptive radiation of freshwater fishes in North America (Pearson and Pearson 1989). Large-floodplain rivers (sometimes called "Great Rivers"), particularly the Ohio and Mississippi, are inhabited by a distinctive assemblage of fishes. Shovelnose sturgeon, paddlefish, skipjack herring, mooneye, emerald shiner, river shiner, and blue sucker are among the Great River species that occur in the Ohio River. The Great River assemblage of the Ohio has a higher faunal resemblance to other large rivers such as the Wabash, Illinois, and Mississippi than to its tributaries like the Scioto, Kentucky, and Green Rivers (Burr and Page 1986)

4.7.1 Early Accounts of Ohio River Fishes

Accounts of fishes collected from the Ohio River are not reliable prior to 1920 in terms of relative abundance because such accounts are typically anecdotal, but they are useful in understanding changes that have occurred in the fish community since that time. Constantine Rafinesque provided the earliest account of Ohio River fishes (Krumholz

1981). In "Ichthyologia Ohiensis" (1820), Rafinesque described and commented on the abundance of over 100 new species of fishes he had observed while traveling down the Ohio in the summer of 1818. Many of these species are no longer recognized, but careful consideration of Rafinesque's work led Pearson and Krumholz (1984) to conclude that Rafinesque had observed 52 species of fishes.

Records on Ohio River fishes from 1820 to 1920 are scarce, although many human actions affected the river's environment during that time, including the clearing of forests and draining of wetlands with the arrival of settlers from the Eastern U.S. Preston and White (1978) observed that after about 1900, increased siltation and turbidity caused changes in fish populations with black bullhead, goldeye, skipjack herring, gizzard shad, and spotted bass increasing in numbers. In 1885, the Corps began to install a series of wicket dams which were raised under low flow conditions and collapsed under higher flows, thus allowing tows and fish to pass upstream or downstream over the dams rather than through locks or gates on the dams, as occurs with the present generation of high-lift locks and dams. As the following sections illustrate, canalization of the Ohio River would have profound effects on its fishes.

4.7.2 Changes in the 20th Century

In 1909-1911, the U.S. Congress directed the Corps to maintain a 9-foot navigation channel in the Ohio River. This directive culminated in the completion of 50 wicket locks and dams by the late 1920s, providing a 9-foot navigation channel for the Ohio mainstem throughout the year (Pearson and Pearson 1989). Even before completion of the navigation system, various human activities had caused several fish species to decline in abundance by the early 20th century, including the lampreys, shovelnose sturgeon, paddlefish, muskellunge, and blue sucker. Fishes reported from the Ohio mainstem prior to 1920, but not collected since that time include the least brook lamprey, Alabama shad, hornyhead chub, Ozark minnow, and mud, longhead, crystal, and gilt darters (USFWS 2000). The crystal and gilt darters were already scarce species, which disappeared after their riffle habitats were inundated by the wicket dams (Pearson and Krumholz 1984).

As discussed in more detail in Chapter 3, "Water Quality," rapid growth of the human population in the Ohio basin during the first half of the 20th century led to larger inputs of domestic sewage, industrial effluents, and acid mine drainage. The pollution was concentrated in the upper river and immediately below Cincinnati and Louisville. Fewer people lived in the lower portion of the river and several large tributaries provided additional dilution, as is true today (Pearson and Pearson 1989). By 1950, abundances of lake sturgeon, shovelnose sturgeon, muskellunge, bigeye chub, and blue sucker were greatly reduced while gizzard shad, emerald shiner, freshwater drum, and the introduced common carp had increased in abundance (Pearson and Krumholz 1984). In the last half of the 20th century, actions of ORSANCO and implementation of the CWA and its amendments led to considerable progress in reducing point source pollution with the subsequent recovery of many fish species, as discussed in the following section.

As the series of wicket dams were being completed, the Corps constructed a new type of gated dam at Louisville in 1927. It was important because it was the first high-lift dam on the Ohio River. The new dam's 37 foot lift made it impossible for fish to pass upstream from Louisville except by locking through with tows, by negotiating the small-

gated sections, or by topping the dam at flood stages (Pearson and Krumholz 1984). The Corps' replacement and modernization program begun in 1955 gradually replaced the low, movable wicket dams with fewer high, non-navigable, gated high-lift dams. The present system consists of 17 dams 16 to 37 feet high and three dams 10 to 13 feet high (Dashields, Dam 52, and Dam 53). Dams 52 and 53 will be removed and replaced by Olmstead L/D at RM 964.4.

The present system of dams has altered aquatic habitats by converting the Ohio River from a free-flowing waterway to one of relatively constant width and a minimum maintained channel depth of 9 feet. The modern navigation system, combined with land use and flood control practices in the watershed, has resulted in the inundation and siltation of extensive areas of gravel substrate, preferred by important fish species, particularly in the lower half of the river (Pearson and Pearson 1989). Further, the range and population of such migratory fishes as the lake sturgeon, paddlefish, skipjack herring, and blue sucker have been greatly reduced in the last 80 years (Burr and Page 1986). Concurrently, the high-lift dams created nearly 80 embayments in creek mouths adjacent to the mainstem in the upper half of the river, which offer important habitat for basses and other sunfishes (Preston and White 1978), species more typical of lake-like conditions.

4.7.3 Trends in Abundances and Diversity along the River

A total of 159 species of fish (including introduced species) have been recorded for the Ohio River since the early 19th century (Pearson and Krumholz 1984, Pearson and Pearson 1989). Reports prior to 1920 list 111 species; those from 1920 to 1969 list 121; and those from 1970 through 1988 list 140 species. Combining data from all periods through 1988, 122, 132, and 119 fish species were reported from the upper (RM 0-327), middle (RM 328-654), and lower (RM 655-981) thirds of the river, respectively. Pearson and Pearson (1989) noted that greater species richness in the middle river possibly reflected greater sampling effort and suggested an equal sampling effort in the Ohio's lower third would reveal more species than reported from the upper and middle third, partly because the lower river reaches would draw from the Mississippian center of North American fish distribution. Biomass of all species combined is usually greatest in the lower, larger third of the river. Among the factors affecting species composition and biomass are such environmental conditions as gradient, effects of impoundment, and the actual size of the river (Krumholz 1981). Many fish species have a broad range of environmental tolerances and are wide-ranging in the Ohio River. Outstanding examples of the wide-ranging group include the gizzard shad, stoneroller, bluntnose minnow, creek chub, green sunfish, and bluegill (Burr and Page 1986).

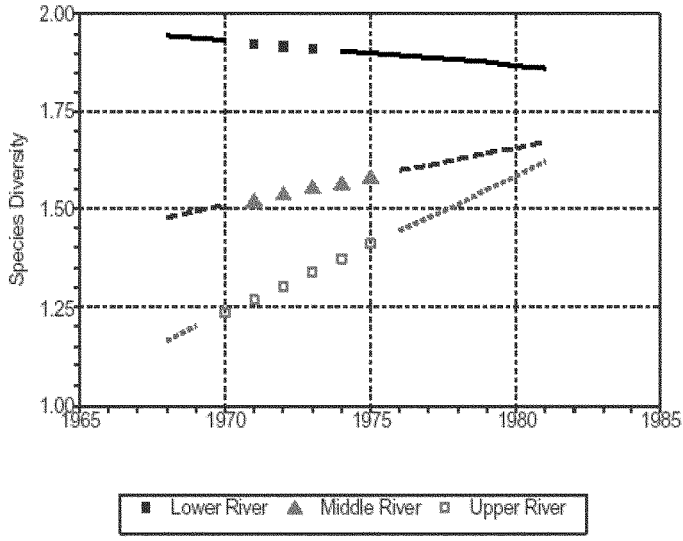
The ORMSS Interagency Working Group (IWG) compiled a highly inclusive list of fish species that might be affected by the CE of navigation in the Ohio River. The list, begun in 2002, comprises nearly 200 species, including fishes that may have been present in lower tributaries of the Ohio prior to impoundment by high-lift dams.

Several studies conducted in the last 20 years by various agencies and researchers in the last 20 years support the upward trend in fish diversity in the upper Ohio River since implementation of the CWA. A review of the rotenone fish sampling data (ORSANCO 1983) illustrated an important and positive trend, which occurred along the river between the late 1960s and early 1980s. An indication of improving water quality was the marked

increase documented in fish diversity as calculated by the Shannon-Weaver Index, with the greatest improvements seen in the upper reaches of the mainstem **(Figure 4-1)**. The Shannon-Weaver Index uses the number of species present and the distribution of individual fish among those species to compare survey findings from year to year and over segments of the river. Shannon-Weaver Index calculations range from three to zero, with three representing a perfectly diverse population (i.e., if there were 100 fish representing 10 species, there would be 10 individuals of each species). In the upper Ohio River, increases were primarily noted in sport and commercially valuable species, which tend to be more pollution-sensitive than other fish species. Fish diversity increased by 40 percent in the upper river, and 13 percent in the middle section. ORSANCO attributed the improvements to increased pH and DO concentrations, and to decreased levels of toxic materials in the river. As **Figure 4-1** illustrates, because indices of diversity combine numbers of species and their relative abundances, higher diversity occurs in the lower river with its larger size and higher biomass. Changes in diversity in the lower river over time were much less pronounced than upstream where historic pollution was much more severe. ORSANCO noted the slight decline in diversity in the lower river from 1.95 in 1968 to 1.88 in 1981 may be related to a lack of data from that section of the river.

Additional research confirmed that many species that disappeared from the upper river during the worst decades of pollution have returned to portions of the river approximating their historical ranges. Between 1984 and 1989, numerous range extensions of mainstem fishes were reported and included 12 species in an upstream direction, 14 species in a downstream direction and six species both upstream and downstream, as listed in **Table 4-3** below (Pearson and Pearson 1989).

FIGURE 4-1
Long-term trends in fish diversity in the Ohio River



SOURCE: ORSANCO 1983.

Further, fish samples collected by Van Hassel et al.(1988) from 1973-1985 in the upper and middle river suggested that range extensions of such river species as the paddlefish, mooneye, spotted gar, river carpsucker, smallmouth buffalo, and white bass were probably direct responses to improvements in water quality in the upper Ohio River.

Changes in species composition and abundances also are indicated in **Table 4-4**, which contrasts the ten most abundant fishes collected in the Ohio River for two different time periods and collection methods. Emerald shiner, gizzard shad, and freshwater drum are the three most abundant species on both lists. However, sauger ranked fourth on the list of fishes collected by electrofishing, though it did not even appear on the earlier list of fishes collected in lock chambers using the chemical rotenone. Other additions to the 1991-2001 list include the bluegill, temperate basses (*Morone* spp.), and silver chub. Deleted from the more recent list are the pollution-tolerant common carp and bullheads, as well as skipjack herring and white crappie.

TABLE 4-3
Fish Range Extensions Reported along the Ohio River since 1983

Direction of Extension & Species	1970-1983 Distribution (Ohio River Mile)	1984-1988 Distribution (Ohio River Mile)
Upstream		
Paddlefish	427-981	341-981
Spotted Gar	846-981	560-981
Threadfin Shad	390-981	341-981
Mooneye	260-981	54-981
Grass Pickerel	597-981	54-981
River Carpsucker	54-981	35-981
Highfin Carpsucker	170-981	54-981
Northern Hogsucker	35-604	13-604
Smallmouth Buffalo	54-981	35-981
Silver Redhorse	35-981	13-981
Rosyface Shiner	35-981	13-981
Striped Bass	126-981	13-981
Upstream and Downstream		
Silverjaw Minnow	54-287	35-605
River Chub	54-470	35-560
Striped Shiner	54-518	35-605
Fathead Minnow	161-279	77-560
Brook Silverside	54-260	35-981
Banded Darter	35-494	13-560
Downstream		
Northern Pike	35-344	35-494
Muskellunge	35-368	35-776
Central Stoneroller	35-571	35-605
Speckled Chub	260-494	260-981
Spottail Shiner	13-54	13-494
Sand Shiner	13-597	13-981
Suckermouth Minnow	177-494	177-981
Blacknose Dace	35-77	35-494
Blue Sucker	54-744	54-981

Direction of Extension & Species	1970-1983 Distribution (Ohio River Mile)	1984-1988 Distribution (Ohio River Mile)
Greenside Darter	54-494	54-560
Rainbow Darter	54-518	54-605
Fantail Darter	54-518	54-981
Johnny Darter	13-494	13-981
Orangethroat Darter	54-77	54-560

SOURCE: Pearson and Pearson, 1989. The authors assumed records from the last 80 miles of the river indicated a distribution down to the mouth (ORM 981).

TABLE 4-4
Ten Most Abundant Fish Species Collected from the Ohio River by Rotenone Lockchamber Sampling (1957-1980) and by Electrofishing (1991-2001)

Rank	Collected in Lock Chambers 1957-1980	Collected by Electrofishing 1991-2001
1	Emerald shiner	Gizzard shad
2	Gizzard shad	Emerald shiner
3	Freshwater drum	Freshwater drum
4	Mimic shiner	Sauger
5	Channel catfish	Mimic shiner
6	Common carp	Bluegill
7	Bullheads (all species)	Channel catfish
8	Skipjack herring	Morone spp. (temperate basses)
9	White crappie	Threadfin shad
10	Threadfin shad	Silver chub

SOURCE: Pearson and Krumholz 1984 and ORSANCO e-mail communication, July 2002.

4.7.4 Introduced and Extirpated Species

Introduced Species

Of the 14 fish species that were introduced into the Ohio River by 1992, only the common carp, goldfish, white catfish, and banded killifish had established reproducing populations (Pearson 1992). Krumholz (1981) described the carp introduction in the late 1800s as the "earliest and most noticeable introduction to date." A native of Asia, the common carp continues to be a substantial component of the Ohio River fish community in both biomass and numbers. Several more recently introduced Asian carps species, however, are now causing serious concern among fisheries biologists and recreational users in the lower mainstem.

Four additional species of Asian carps were introduced into the natural system over a period of years -- the grass, silver, bighead, and black carp. These species are of increasing concern for several reasons:

- All except black carp now have reproducing populations in the Ohio River, but are of little value to sport fishermen.
- Grass carp feed aggressively on aquatic vegetation, compete with native fishes for food and space and destroy fish and waterfowl habitat by eliminating

vegetation (Pflieger 1975). Unlike grass carp, common carp uproot vegetation as part of their feeding behavior.

- Silver and bighead carp are effective planktivores. Native larval fish also feed on plankton and may compete with bighead and silver carps for food resources if plankton becomes limiting. Competition requires a limited resource; plankton are not limited at this time, although proper species and sizes may not be sufficiently available when needed by larvae of native fishes. Some dietary overlap may also exist with native planktivores such as gizzard shad, paddlefish, and bigmouth buffalo. Larval fish must compete with these filter-feeding carp, while they risk being eaten themselves.
- Studies of the population dynamics of these species are complicated by the tendency of bighead and silver carp to startle easily and launch themselves out of water, potentially seriously injuring biologists monitoring them (Perea and Gittinger 2002).
- A triploid (sterile) black carp has been documented for Horseshoe Lake in southwestern Illinois near the confluence of the Ohio and Mississippi Rivers (Caswell, personal communication). Black carp are molluscivorous with the potential to seriously impact already precarious populations of native mussels and snails if they enter the Ohio River ecosystem. Further, at all life stages black carp will compete for food with native fish species. Animals of riparian zones, including turtles, waterfowl, raccoons, and muskrats also are likely to be affected through competition for food. Under the authority of the Lacey Act Amendments of 1981, the USFWS is in the process of listing the black carp as an injurious wildlife species. Such a listing would prohibit the importation and interstate transport of black carp (http://southeast.fws.gov/hotissues/Black_Carp_FS.pdf).

  According to a comment received from the USGS during review of this document, black carp do not compete for food with native fishes at all life stages. They will compete for food with native molluscivores if food resources are limited. Animals of riparian zones are only likely to be affected if they are dependent upon molluscan resources and these resources are limited in availability.

The 2005 publication (Nico, et al) will help develop a mitigation strategy for the Ohio River mainstem and tributaries. The USFWS also developed a National Asian carps Management and Control Plan, which was released for public comment in August, 2006. The plan, which is being developed by multiple resource management partners, including Canadian agencies, seeks to integrate prevention and control activities to limit the further distribution and negative impacts of these four nuisance species. The potential impacts of Asian carps on the Ohio River native fish communities may prove a serious challenge to fish community sustainability. Because relatively little is known about Asian carps' preferred habitats, prospects for long-term reproductive success, and best sampling methods, they also present challenges in adaptive management.

Extirpated Species

Pearson and Pearson (1989) reported 19 native species that had not been reported from the Ohio River since 1970. Most significant were three large river species: the lake

sturgeon, Alabama shad, and crystal darter. Pearson and Pearson suggested that navigation dams, including those located on tributaries, may interfere with migratory species such as paddlefish, sturgeons (shovelnose and lake), and shad, while inundation of riffles and siltation probably reduced the crystal darter. Recently lake sturgeon have been recorded from the Ohio River along Lewis, Union, Livingston, and Ballard Counties, Kentucky, although the species continues to be rare (Compton et al. 2004). Compton et al. suggest possible origins of recent specimens include a remnant Ohio River population and migrations from Missouri (where they have been stocked) or the Wabash River in Indiana.

4.7.5 Species Listed of Special Concern under the Endangered Species Act

In 1987, Johnson reported 18 percent (28 species) of Ohio River fish species are considered rare enough to be protected by law in one or more states bordering the Ohio River. An additional 13 percent (21 species) are of special concern in one or more states. Regarding Ohio River fishes listed under the federal Endangered Species Act (ESA), five species have been identified as species of special concern (SSC): the paddlefish (*Polyodon spathula*), blue sucker (*Cycleptus elongatus*), crystal darter (*Ammocrypta asprell*a), Eastern sand darter (*Ammocrypta pellucida*), and longhead darter *(Percina macrocephala*). Among the reasons for SSC designation are the species: 1) has a significant vulnerability to habitat modification or human exploitation which may result in its becoming a threatened species in the foreseeable future if effective management is not initiated, 2) may already meet certain criteria for designation as a threatened species but conclusive data are lacking, 3) has not significantly recovered from past depletion, or 4) may occupy such an essential ecological niche that its further decline would adversely affect other species to a significant degree (FFWCC 2004).

An Endangered Species Act (ESA) Section 7 consultation for on-going operation and maintenance of the entire Ohio River navigation system is in progress. Through the Section 7 process, the USFWS is working with the Corps 1) to provide information about listed, proposed, and candidate species and critical habitat in the ORMSS project area, 2) to proactively emphasize the identification and informal resolution of potential species conflicts, and 3) to advise the Corps on how to avoid adversely impacting listed species and their habitats (USFWS & NMFS 1998).

4.7.6 Fish Habitats

Changes in fish communities of the Ohio River during historical times reflect available spawning habitats and human alterations. Reproductive modes are important in evaluating fish communities because reproductive failure in response to environmental stressors leads to rapid decline and elimination of fish populations. Spawning habitat in the mainstem is critically important to Ohio River fishes because most species are spawned in the mainstem, not in tributary streams or recently created embayments (Pearson and Krumholz 1984).

Fish guilds, defined as groupings of species capable of exploiting the same environmental resources or habitats in similar ways, provide a framework for reflecting upon changing environments. Balon, as cited by Pearson and Krumholz (1984), developed a reproductive guild classification for fishes that considers behaviors, preferred spawning substrates, and morphological adaptations of eggs and larvae in relation to predation and the availability of oxygen. Pearson and Krumholz used Balon's classification system as a

framework for arranging Ohio River fishes into guilds based on their known spawning habits. They assigned 128 of the Ohio mainstem's 159 species into 13 guilds that they believe explain how human influences on the physical nature of the river have altered fish communities.

Early historical accounts of the river describe extensive reaches of clean gravel substrate in near-shore zones. Pearson and Krumholz note most fish species in the river were and are lithophils, species that spawn over clean gravel or rock. Siltation and inundation concomitant with agricultural clearing and channelization altered these spawning substrates. Consequently, lithophils such as the shovelnose sturgeon, lake sturgeon, redhorses, blue sucker, and paddlefish declined in abundance while pelagophils, which produce floating eggs or larvae, increased in abundance. The three most abundant species during the period of quantitative collections since 1957 are the emerald shiner, gizzard shad, and freshwater drum. All have eggs or larvae that float in the water column. Three other species with pelagic eggs, however, have not been as successful and are either rare (burbot) or low in abundance (mooneye and goldeye). The burbot always has been rare in the river, but the other three species are believed to migrate upstream before spawning and may be thwarted by dams (Pearson and Krumholz 1984).

According to Pearson and Krumholz, fishes such as carpsuckers and buffalofishes that spawn over vegetation and debris (usually from terrestrial sources) have maintained their relative abundance in the river. Nest-guarding species such as sunfishes, largemouth bass, smallmouth bass, and spotted bass are only abundant in protected embayments where spawning sites are available. Pearson and Krumholz theorize that disturbances from towboat wakes prevent successful spawning in the mainstem for almost all sunfish and bass species, but not white crappie. Van Hassel et al. (1988) observed overall that Ohio River habitats favor non-guarding (non-nesting), open substrate fish species. Pearson and Krumholz identified seven macrohabitats available to fishes in the Ohio River **(Table 4-5)**.

TABLE 4-5
Fish Habitat Types in the Ohio River

Habitat	Extent of Habitat	Substrate	Spawning Suitability	Other Comments
Main channel	At least 9 ft. deep and 300 ft. wide	Usually sand, but gravel, rubble and bedrock possible	Limited (e.g., freshwater drum, gizzard shad)	Current of at least 0.5 ft./sec. always present Rooted vegetation absent
Main channel border	Between main channel & shore-debris zone	Sand or silt, with occasional extensive gravel or rubble	Pelagophils & lithophils (e.g., blue sucker, redhorses)	Rooted vegetation absent
Shore-debris zone	5-150 ft. out from shoreline	Sand or silt with sunken logs & branches partially buried	Primarily vegetation & nest spawners (e.g.,buffalo,gar)	Rooted vegetation may be found
Tailwaters	Extending 0.5 mi. below navigation dams	Sand, gravel or bedrock	Local lithophils (e.g., sauger, walleye)	Extensive turbulence & elevated oxygen occur. Usually no rooted vegetation

Habitat	Extent of Habitat	Substrate	Spawning Suitability	Other Comments
Side channels	Areas separating near- shore islands from mainland	Soft-bottomed & often lined with eroded banks	Primarily nest spawners & some vegetation spawners (e.g., sunfishes, black basses)	Trees which have slumped into channel may be present. Contain running water at normal pools
Sloughs and embayments	Varying in size, depending on river water levels	Soft-bottomed, often with standing & submerged timber	Very important for nest spawners (e.g., sunfishes, black basses)	May have rooted vegetation No appreciable current at normal pools
Creek mouths & flooded channels	Variable in size & extent of flooding	Often steep-banked & soft-bottomed, but may have coarser substrates	Important for small stream species that only stray into main-stem (e.g., creek chub, stoneroller)	High gradient tributaries prevail above RM 450 while low gradient tributaries prevail below RM 450

SOURCE: Pearson & Krumholz 1984.

Islands, more numerous in the upper and lower river than in the middle third, also are excellent fish habitats. They are important to spawning fishes because:

- They offer resistance to currents, which in turn may result in an increase in current speed on one or both sides of an island head, which results in clearing of coarse sand or gravel bars where lithophils can spawn.
- They often are separated from the mainland by narrow back channels, which are sheltered from waves generated by tows and recreational craft.
- Narrow back channels often are bordered by undercut banks and fallen timbers, which can provide nesting cavities for certain species, including catfishes.

The influence of tributaries on community structure of fishes in large midwestern rivers is still not well defined. Pearson and Krumholz (1984) found no evidence that tributaries are important for spawning of Ohio River fishes. They suggested that tributaries serve as refuges where mainstem fish can avoid environmental stressors, as well as serving as reservoirs for small stream inhabitants such as the stoneroller, creek chub, northern hog sucker, madtoms, topminnows and darters, which stray only occasionally into the Ohio mainstem. Emery (personal communication) believes some species rely almost exclusively on tributaries for spawning, but are listed as Ohio River species because they are collected there as adults. Emery's observation corroborates Curry and Spacie's (1979) findings, cited by Reash (1999) that the importance of tributaries in recruitment of mainstem fish populations is species specific.

Sheehan et al. (1994), studying winter habitat and overwintering requirements for four river species in the Upper Mississippi and Illinois Rivers, found that fish migration into backwater winter habitats was influenced primarily by water temperature and not by river stage or photoperiod. Based on swimming performance tests, the ability of fish to winter in flowing water habitats is diminished with falling temperatures. The study also found that smaller fish in general are less capable of overwintering in channel habitats.

Details of winter habitat studies conducted by Garvey et al. (2003) are presented later in the section titled "Studies Concerning Specific Impacts on Fishes."

4.7.7 Indices of Biotic Integrity

Indices of Biotic Integrity (IBI) are used to assess the condition of water bodies by direct evaluation of biological attributes. IBIs involve integration of structural, ecological, trophic, and reproductive attributes of fish assemblages at multiple levels of organization (Karr 1981; Karr 1986; Fausch et al. 1990; as cited in Emery et al. 2003). ORSANCO has used the Modified Index of Well Being (MIwb) and, more recently, the Ohio River Fish Index (ORFIn) to assess the biotic integrity of the Ohio River.

The MIwb quantitatively measures the relative health of fish communities using four measures of fish communities that traditionally have been used separately: numbers of individuals, biomass, and the Shannon Diversity Index based on numbers and weight (two separate calculations). ORSANCO (1992) adapted the MIwb to prevent attainment of high scores from degraded sites with large numbers of pollution tolerant fish. A positive correlation between the MIwb and water quality, therefore, illustrates that less impacted stream segments support a larger variety and abundance of fish than stressed segments (Ohio EPA (OEPA) 1987). An analysis of 1989 OEPA electrofishing data and ORSANCO lockchamber data from 1968 through 1990, in general, indicated improving conditions in the fish communities from upstream to downstream, reflecting less concentrated human activity, lower levels of pollution, and less habitat deterioration (ORSANCO 1992). The study identified three river reaches that showed sags in the MIwb as follows:

- Montgomery L/D (RM 31.7) to Pike Island L/D (RM 84.2) - affected by point sources from heavy industry and acid mine drainage

- Racine L/D (RM 237.5) to Byrd L/D (RM 279.2) - influenced by heavy industrial discharges from the Kanawha River

- Meldahl L/D (RM 436.2) to McAlpine L/D (RM 606.8) - affected by nonpoint pollution from urban runoff and combined sewer overflows (CSOs) and chronic operation problems at the Mill Creek wastewater treatment plant in Cincinnati.

During the past several years, ORSANCO and other agencies have collaborated to develop an IBI specifically tailored to the distinctive ecological characteristics of the Ohio River. The resulting index, the Ohio River Fish Index (ORFIn) measures 13 attributes of fish communities that either respond predictably to measures of human disturbance or reflect desirable features of the Ohio River, as **Table 4-6** presents:

TABLE 4-6
ORFIn Metrics, Selection Rationale and Observations to Date

ORFIn Metric	Rationale for Metric Selection	Observations to Date*
Number of native species	Focuses on native species diversity by excluding nonindigenous species and hybrids that indicate a lack of biotic integrity	1) # of native species decreases from upstream to downstream, possibly related to river geomorphology. 2) # of native species was greater at deeper sites with coarser substrates than at shallower sites with more sand and fines. 3) Native species also declined with degraded water quality.
Number of sucker species	Suckers are a major component of Ohio River fish fauna. Round-bodied suckers are especially sensitive to habitat and water quality degradation and long life span provides a metric influenced by long-term environmental changes.	1) # of sucker species was significantly correlated with coarse substrates, submerged vegetation, woody cover, and conductivity and negatively correlated with elevated temperature, sands and fines, and degraded abiotic conditions. 2) # of round-bodied suckers decreased downstream.
Number of centrarchid species	Modified from Karr's 1981 IBI to include black basses (*Micropterus* spp.), the dominant centrarchids in Ohio River pool habitats	1) # of centrarchid species did not vary significantly from upstream to downstream 2) # of centrarchid species was greater at sites over coarse substrates and at sites with abundant woody or vegetative cover and lower at shallower sites with finer or embedded substrates. 3) Species richness declined with increasing turbidity and water temperature.
Number of Great River species (fishes typical of large flood-plain rivers)	Represents fish species expected to predominate in Great Rivers and expected to decline with loss of associated floodplain habitat	# of Great River species was not strongly correlated with any abiotic factors, but this metric was retained because it expresses historical conditions in the Ohio River.
Number of intolerant species	Reflected the highest levels of biotic integrity.	1) # of intolerant species decreased from upstream to downstream 2) They also decreased significantly with degraded water quality and at sites with increased sand, fines, and highly embedded substrates.
% Tolerant individuals	Represent the worst conditions in the Ohio River prior to implementation of the CWA in 1972	1) Tolerant species are becoming increasingly scarce as impacts of degradation are becoming more localized. 2) % of tolerant species increased with higher turbidity and lower dissolved oxygen levels.
% Simple lithophils (fish species that scatter eggs among gravel	Represents reproductive guilds that are most sensitive to substrate disturbance and degradation	1) Simple lithophils decreased from upstream to downstream, presumably as coarse substrates became increasingly less common. 2) They also declined with increased

ORFIn Metric	Rationale for Metric Selection	Observations to Date*
substrates without parental care)		temperatures.
% Nonnative individuals	Measures the degree to which non-indigenous species and hybrids have reduced biotic integrity in the Ohio River	% Nonindigenous species was significantly correlated with increased turbidity.
% Detritivores	Represents fishes that feed on dead plants or animals or their wastes	% Detritivores increased with increasing proportions of sand and fine substrates and higher water temperatures.
% Invertivores	Measures the proportion of specialized sight feeders that feed on insect and other small invertebrates	1) % Invertivores decreased from upstream to downstream. 2) % was higher at deeper sites with coarse substrates and lower at sites with finer substrates and higher temperatures.
% Piscivores	Represent fishes at the top of the aquatic food web	1) % Top piscivores increased slightly from upstream to downstream. 2) They also increased with increased depth and woody cover, but declined with increased water temperature.
Relative number of DELT abnormalities (deformities, ecoparasites, lesions or tumors)	Measures the effects of contaminants, diet and overcrowding	# of DELT abnormalities increased with increased turbidity and at sites with low dissolved oxygen.
Catch per unit effort (CPUE)	Measures community productivity	Greater productivity is expected to reflect greater biotic integrity.
* Based on data collected from by nighttime electrofishing from 709 Ohio River reaches from 1991-2001. SOURCE: Emery et al. 2003.		

The potential range of ORFIn scores is 1- 65. ORFIn is sensitive to a wide range of habitat and water quality conditions and is being used to develop numeric biological criteria for the Ohio River for eventual incorporation into ORSANCO's Pollution Control Standards (Emery and Vicory 1998). The application of ORFIn to 2000-2001 fish population data indicated that only seven miles of the Ohio River in the Meldahl Pool (RM 354-361) are impaired for aquatic life (ORSANCO 2002), thus, indicating an overall improvement in conditions compared to the earlier MIwb. ORFIn scores from non-outfall sites were significantly higher than those from sites within the first 500 m downstream from point sources of chemical, thermal, and wastewater effluents. ORFIn scores were lowest at shallow sites with sand and fine substrates and higher at deeper sites with coarse substrates, clear water and cooler temperatures (Emery et al 2003), conditions favorable to simple lithophilic fish species typical of the preimpoundment Ohio River. Evaluation and refinement of ORFIn as a sustainability assessment tool will continue over the next several years.

4.7.8 Activities of the Ohio River Fisheries Management Team

The Ohio River Fisheries Management Team (ORFMT) was formed in 1990 in response to a U.S. Supreme Court decision on multi-state ownership of the river and recognition of the need for long-term collaborative fisheries management efforts by the six

states bordering the river. The ORFMT, composed of fisheries personnel from the six bordering states, focuses on species with recreational importance and has facilitated the establishment of fishing license reciprocity and standardization of recreational fishing regulations up and down the Ohio River.

In addition, the ORFMT is implementing cooperative projects to restore and improve Ohio River fishery resources based on several management principles. The ORFMT members:

1) will implement strategies to improve the health, integrity, and productivity of the Ohio River ecosystem
2) will manage Ohio River fishery resources to sustain a harvestable surplus by implementing appropriate management strategies
3) recognize stocking as an appropriate management strategy, but encourage a thorough analysis of all relevant factors to ensure that stocking does not adversely affect existing fish populations or other aquatic resources
4) will manage, preserve, protect, enhance, and acquire habitats necessary for a healthy and diverse Ohio River fish community
5) will strive to provide additional access and fishing opportunities for Ohio River anglers
6) will conserve the genetic diversity of Ohio River fish
7) will implement strategies to prevent, control and abate the introduction of non-indigenous aquatic nuisance species and
8) will protect, maintain and restore Ohio River biodiversity and species richness. (ORFMT, not dated (a)).

Fisheries management plans have been developed for Ohio River populations of black bass and paddlefish and are under development for walleye and sauger.

The black bass management plan, including smallmouth, largemouth and spotted bass, recognizes the importance of these species to Ohio River anglers and seeks to develop a greater understanding of the dynamics of black bass fishing in the river. To improve black bass habitat along the river, the ORFMT plans to work with the Corps to identify opportunities for water level stabilization, embayment dredging and maintenance of snags and laydowns. Other activities include working with the USFWS and other groups to improve water quality and minimize the effects on black bass habitat of such activities as sand and gravel mining, barge fleeting and development (ORFMT, not dated (b)).

The paddlefish is an important interjurisdictional fish, which has had highly variable management strategies among the six states bordering the Ohio River. It is categorized as extirpated in the upper river (Pennsylvania), threatened (Ohio) and protected (West Virginia) in mid-river reaches, but commercially harvested in mid-river and lower river reaches (Kentucky, Indiana, and Illinois). Further, because of the decline of European sturgeon stocks, paddlefish have been increasingly harvested to meet worldwide demand for caviar. Kentucky and Indiana licensed 399 commercial paddlefish harvesters during 2000 alone. Snagging of paddlefish by sportfishers also is popular in some reaches. Management strategies outlined in the ORFMT's paddlefish management plan (2001) include: 1) monitoring abundance, 2) refining quantification of paddlefish movement, 3)

quantifying exploitation, 4) monitoring the commercial harvest, 5) monitoring sport fisheries, 6) improving data management, and 7) providing public information (ORFMT 2001).

The ORFMT currently involves a small group of resource managers with limited financial resources. The effectiveness of ORFMT's management plans will be better understood as collaboration increases, management strategies are implemented, and plans are developed for additional species or assemblages.

4.8 STUDIES CONCERNING SPECIFIC IMPACTS ON FISHES

Because of their conspicuousness, as well as their ecological, economic, and recreational importance, many studies have been conducted to determine the effects of various human actions on fishes of the Ohio River. Several studies have considered the specific effects of navigation infrastructure, commercial transportation, and power generation. Some studies discussed in the sections below were specifically designed and conducted to address data gaps identified in the ORMSS scoping process.

4.8.1 Upstream Fish Passage at Ohio River Mainstem Dams

Recent literature on the ecology of large rivers suggests that longitudinal connectivity is important to ecosystem structure and function of fishes with life-stage specific habitats that are spatially separated along a river system (Vannote et al.1980; Ward and Stanford 1995; Stanford et al.1996; as cited in Knights et al. 2003). While salmon studies in the Pacific Northwest perhaps most frequently illustrate the importance of longitudinal connectivity, numerous other studies indicate that longitudinal connectivity may also be important to sustaining the bioproduction and biodiversity of migrating fishes inhabiting Great Rivers like the Ohio. Examples of such migratory species include sturgeon, paddlefish, and herrings, as studied by Auer 1996; Johnson et al.1997; Bergkamp et al. 2000 (cited in Knights et al. 2003). If such species are intermittently or completely denied access to spawning habitats or encounter delays in reaching these habitats, variable recruitment or possible extirpation of existing stocks may result. Further, barriers to longitudinal movement affect freshwater mussel populations by deterring movement of fish species that serve as hosts during critical stages in the mussel life cycle.

Literature on native fishes in the Ohio River suggests that many species are migratory during the reproductive phase of their life cycles or move longitudinally between feeding and overwintering areas. Knights et al. (2003) undertook a study for ORMSS to more fully assess upstream fish-passage opportunities through Ohio River mainstem dams. The study related historical hydraulic conditions at the dams to swimming capabilities of select native and non-native fishes to determine if dams are restricting upstream movements of fishes. Additionally, abundances and distribution of 44 target species were examined in relation to upstream fish-passage opportunities at mainstem dams. Fish species included in the study were selected upon consultation with the ORMSS IWG and review of pertinent literature on the migratory behaviors of native and nonnative fishes in the Ohio River. Species selected included:

- widely distributed species or groups including paddlefish, skipjack herring, mooneyes, buffalofishes, temperate basses, sauger, and walleye;

- species with restricted distribution including lake sturgeon, shovelnose sturgeon, American eel, blue sucker, and blue catfish; and
- several nonnative, invasive species, including silver and bighead carp.

A comparison of the swimming speeds of target fishes with estimated water velocities through the gates of mainstem dams during various conditions and reports of upstream movement of target fishes through dams suggest that upstream fish passage opportunities generally occur during open river rather than controlled conditions at dams. Open river conditions occur when dam gates have been lifted clear of the water and are no longer controlling water levels upstream of a dam. Therefore, at open river, the water surface elevation immediately downstream of the dam in the tailwater is about equal to the water surface elevation immediately upstream of the dam. An analysis of historical water elevation data at Ohio River mainstem dams revealed that the frequency of open river by calendar week (hence, the potential for fish passage) varied spatially along the river by dam and temporally with discharge. The general spatial pattern of open river indicated that the potential for fish passage decreases from downstream to upstream. Consequently, the potential for fish passage through the gates of navigation dams is low to high at dams in the Louisville District (Dam 53 through Markland – eight dams), low to moderate at Huntington District dams (Meldahl through Willow Island – six dams), and low at Pittsburgh District dams (Hannibal through Emsworth – six dams). In general, open river conditions were more frequent during winter and spring, coinciding with the high-flow period from December through June, and generally were nonexistent during summer and fall, coinciding with the low-flow period. An additional avenue for fish passage is likely during flood conditions when fish can occupy flooded areas to move around dams. Pre- and post-dam abundance and distribution data for target species, along with life history information, suggest that mainstem dams on the Ohio River affect some species. Detailed information on life histories, swimming abilities, abundance, distribution, and fish-passage issues by species or major groups is included in Knights et al. (2003).

Fish species with greater prolonged or burst swimming speeds and with behavioral or morphological characteristics, such as those able to take advantage of lower velocities in the upper portion of the water column, are more likely to pass upstream through a dam (Knights, et al. 2003). These fish include Alabama shad, skipjack herring, goldeye, mooneye, striped bass, white bass, yellow bass, paddlefish, bighead carp, common carp, grass carp, silver carp, carpsuckers, white sucker, buffaloes, redhorses, largemouth bass, sauger, walleye, and freshwater drum. Fishes less likely to pass upstream through dam gates include blue sucker, spotted sucker, channel catfish, blue catfish, sturgeons, and northern pike (Knights, et al. 2003).

Knights, et al. (2003) suggested that many variables other than fish passage through dams are likely contributing to the present abundance and distribution of fish species in the Ohio River. Some of the variables are historical stressors, recruitment from upstream areas through drift of larval fish, and the likelihood of some species fulfilling their life cycle requirements within a single pool.

A contemporaneous ORMSS study of 121 Ohio River fish conducted by Wells (2003) analyzed fatty acid profiles of migratory sauger and white bass from six pools (Hannibal, Belleville, Greenup, Meldahl, Cannelton, and Smithland) to determine if genetic variations occurred among these populations. Using fatty acids as a biological

marker, the study indicated the existence of two distinct subpopulations of sauger and white bass, roughly separated into the upper and lower Ohio River reaches.

Uncertainty regarding the role of mainstem dams in the reduction in abundance and distribution of the target species remains because of the qualitative nature of pre-dam data and the influence of concomitant stressors, such as water and substrate quality and lack of floodplain connectivity. Despite uncertainties, Knights et al. (2003) suggest that because large river fish populations evolved under conditions less restrictive to longitudinal movement than presently exist, conditions created by mainstem dams probably affect the distribution, abundance and productivity of migratory species by imposing limitations on life cycle completion and interactions among localized fish populations. Analyses of open river frequency and critical lift (the minimum dam lift that allows fish passage between pools) suggest that Ohio River fishes are now more restricted longitudinally than under pre-dam conditions. Information on the abundance and distribution of highly migratory species (e.g., American eel, paddlefish, and Alabama shad) lends credence to the assertion that restricted longitudinal movement negatively impacts these fishes. Knights and his colleagues concluded that dams on large rivers may negatively impact potentially connected fish populations by reducing available habitat and immigration among subpopulations, thus making such subpopulations less resilient to disturbances and more vulnerable to decline. Further, their study recommended moving beyond species-specific and site-specific management towards more systemic considerations that could include both operational and structural measures to improve fish passage at mainstem dams on the Ohio River.

Four additional studies undertaken for ORMSS related to fish movement and passage in the Ohio River were conducted by the West Virginia Department of Natural Resources (WVDNR) in coordination with the ORFMT. These studies, which corroborate some of Knights et al. (2003) findings, are briefly summarized below:

1) The Fish Passage Direct Observations Study, conducted at Winfield L/D on the Kanawha River, was undertaken to ascertain:

- if fish community structure differs between lock chambers and tailwater areas
- what hydrologic conditions promote passage of six target species used in the study, and
- the short-term movement patterns of the target species.

Target species were selected to represent large river fishes occupying different behavior and habitat guilds and included hybrid striped x white bass, sauger, skipjack herring, channel catfish, smallmouth buffalo, and freshwater drum. In general, the study showed that large river migratory fishes (e.g., white bass, skipjack herring, and sauger) were more common in tailwater areas than in the lock chambers, while species typical of more lentic (lakelike) conditions (e.g., channel catfish) were more common in the lock chambers. The findings support ORSANCO data that have indicated that fewer large river species are collected in traditional lock chamber surveys than expected based on their overall abundance in the river. Further, the findings of the direct observation study led to the reasoning that many migratory species are not attracted to typically low flow conditions in lock chambers and, therefore, miss opportunities to pass through lock/dam complexes during typical navigational lockage operations.

2) The Fish Tagging and Recovery Study, conducted in nine tailwaters areas along the Ohio River, was undertaken to:

- determine movements of three target migratory species (sauger, white bass, and paddlefish) and
- ascertain hydrologic conditions that may promote movement of the target species.

In general, this study supported the findings of the Fish Passage Direct Observations Report and indicated that migratory fishes' affinity for flowing waters inhibits them from gravitating to lock chambers. Instead, their interpool movement appears to be facilitated by more open river conditions. For example, higher fish passage rates occurred at R.C. Byrd (RM 279.2) where open river conditions occurred 9.4% of the time compared to Belleville L/D (RM 203.9) and Willow Island L/D (RM 161.7) with open river conditions occurring 1.4% and 1.6% of the time, respectively.

3) The Recreational Fish Survey, conducted on more than 8,500 angler trips at eight tailwaters for at least a 12-month period covering all seasons, was undertaken to:

- determine recreational angling effort along the Ohio River
- obtain catch and harvest data for selected sport species
- provide demographic trend information, and
- compare current recreational angling activities with results from previous studies.

Tailwaters were the focus of this study because migratory fish species congregate in tailwaters making surveying anglers who congregate nearby in response to these concentrations of fishes much more productive. Tailwaters often concentrate migratory fish species as dams limit upstream migration of these species. Schell et al. (1996) reported that while tailwaters comprise only a small percentage of available angling habitat, they generated more than 66 percent of the total recreational catch for the Ohio River. Although angling efforts and species sought varied somewhat by tailwater, targeted angling efforts throughout the river were directed towards percids (24%), catfish (17%), black basses (16%), and paddlefish (10%). In most tailwaters, however, the number of anglers fishing for "any species" exceeded the number targeting a single species or group and totaled 33 percent of anglers on the river overall. Geographic differences also were observed in species sought. For example, percids were sought in more upstream tailwaters while catfish were sought more frequently in downstream tailwaters. Paddlefish were only sought in the Markland and Myers tailwaters. Consumption advisories may, to some extent, explain that fewer fish were harvested (kept) by anglers in the more industrialized upper river than in the more rural lower river. Lower angling effort compared to past surveys may be related to higher river levels and increased homeland security measures implemented following September 11, 2001. Increased security measures limited angler access at some tailwaters.

4) The Glochidial Infestation Study, during which fish were collected from ten areas, was undertaken to:

- determine mussel glochidial infestation rates of a wide diversity of Ohio River fish species and
- ascertain potential impacts of restricted fish passage on host/mussel glochidial relationships.

A total of 31 fish species representing a wide range of behavioral and habitat guilds were collected primarily in tailwaters because of the potential presence of mussels in these more free-flowing sections of the river as well as the congregation of fish just downstream from locks and dams. Of 1,067 fish collected, 536 were examined for infestation with the mussel glochdial life stage. Only four individuals - a longnose gar, gizzard shad, skipjack herring, and spotted bass – were infested. These four species previously have been reported as fish hosts for species of Ohio River mussels. Due to the low numbers of glochidia found during this study, no conclusions could be made related to the study objectives, especially as related to fish passage. The study, however, cited similar low infestation rates reported by Weiss and Layzer (1995) for fish from the Green River in Kentucky, a major tributary to the Ohio River. The influences of flow rates, water temperature, river location and season on infestation rates were not discussed in the study's results.

4.8.1.1 Longitudinal and Lateral Connectivity in the Ohio River

Hoskins, Koryak and Stafford (2003) examined the relative contribution of tributaries and mainstem populations to reestablishment of fish populations in the upper Ohio River as follows:

> "Historically, ... the upper Ohio ... River ... maintained very poor water quality (Shapiro et al. 1967) and did not support any substantial fisheries. The demise of fishes from rivers of the Pittsburgh region during the late nineteenth and most of the twentieth centuries has been examined in detail by ORSANCO (1962), Preston and White (1978), Trautman (1981), Pearson and Krumholz (1994), and others. Species of smaller rivers and stream habitats persisted in more remote, non-urbanized and unpolluted refuge headwaters. However, those species associated with large river ecosystems such as sauger (*Stizostedion vitreum*), spotted bass (*Micropterus punctulatus*), freshwater drum (*Aplodinotus grunniens*), mooneye (*Hiodon tergisus*), goldeye (*Hiodon alosoides*), river carpsucker (*Carpiodes carpio*), highfin carpsucker (*Carpiodes velifer*), silver chub (*Hybopsis storeriana*), river shiner (*Notropis blennius*), the buffalos (*Ictiobius* spp.), lake sturgeon (*Acipenser fulvescens*), shovelnose sturgeon (*Scaphirynchus platorynchus*), paddlefish (*Polyodon spathula*), and other species became locally extinct due to the pollution. Historically, the water quality of five Corps reservoirs and two large private utility hydropower reservoirs in the upper Ohio River drainage basin was so grossly degraded that these systems were completely devoid of fish life (Koryak et al. 2001).

The improvements in water quality that began in the 1970s allowed fish to invade and recolonize reclaimed waters. This restoration of local river fisheries has been discussed by Preston and White (1978), Pearson and Krumholz (1984), and Koryak and Hoskin (1994). The first species to appear were those that had persisted in upstream

refuges. Recolonization by many of the large river habitat species occurred later and apparently originated from distant downstream areas.

Holland et al. (1984) showed that, depending on their design and operation, navigation dams on larger rivers can be relatively pervious to fish passage. Their observations of recolonization rates along the mainstem Ohio River, lower Monongahela River and lower Allegheny River, which have very heavy commercial barge traffic and frequent year-round lockages, suggest that fishes can generally move upstream through navigation locks. Along the five pools of the upper Allegheny River navigation system, where winter and spring lockages are very infrequent, extirpated fishes were not recolonizing the upstream navigation pools until a program of fish passage lockages was initiated.

Formerly extirpated species of fish are also returning to smaller tributaries of the Allegheny, Monongahela, and Ohio Rivers (Koryak and Hoskin 1994). As water quality conditions continue to improve, this process of recolonization now appears to include, or has the potential to include, utilization of even small recovering local urban and suburban streams by resident and transient populations of fishes.

4.8.1.2 Synthesis of Information on Fish Passage

Upon completion of literature reviews and studies, the extent to which navigation locks and dams may act as barriers to fish movement and the degree to which such barriers may be impacting fish and mussel communities of the river were discussed during a meeting of the ORMSS IWG. These questions and the responses follow:

Q.1. Will the dams be effective barriers to invasive aquatic species?

A.1. The consensus of the ORMSS IWG was that dams will not serve as effective barriers to invasive species but they may slow down the migration. The slowing down may extend the time to look for opportunities to counter invasives. The type of dam may help slow migrations to some extent, but, over the long term, navigation dams will not be effective barriers to non-native invasive aquatic species.

Q.2. Are there operational modifications that could encourage fish movements through lock chambers?

A.2. There may be operational opportunities to encourage fish passage such as were performed at dams on the Allegheny River, but a case-by-case evaluation should be performed at each project. Because evidence suggests that flow is important to encourage fish entrance into lock chambers, one possibility is to provide flow through open locks to draw fish into the chambers. It appears that, at lock and dam complexes where private hydropower plants are present, greater flows from the hydropower units as compared to lock flows may draw fish away from lock chambers and thereby discourage fish movement through locks. Further, there is seasonality in fish migration which is probably related to instinctive pre-spawning movements and subsequent dispersal to feeding areas throughout the growing season.

Q.3. Is there sufficient evidence to support the conclusion that there is an upper river and a lower river fish population?

A.3. In 2003, lower river fish species appeared in the Pittsburgh area. However, there was no consensus regarding existence of upper and lower river populations, with some evidence of three distinct fish communities as suggested by data collected by ORSANCO during fish assessment monitoring since 1993. Discussion ensued about a possible historical division at the Falls of the Ohio River where McAlpine Locks and Dam now exists, although tagging studies by WVDNR indicate the distinction between fish communities occurs at Markland Lock and Dam (the next complex upstream of McAlpine). If distinct fish communities exist, the differences were not attributed to a lack of fish passage and could not be attributed to dams on the rivers. Such differences were likely due to other reasons such as dissimilarity of geological formations and physical habitats from upstream to downstream areas, as well as effects of previous water quality perturbations along the river.

Q.4. Why do we see so little downstream movement?

A.4. Dams may slow down fish movement in a downstream direction but likely do not impede such movement. Downstream movement occurs and has been documented for paddlefish. It is possible that the sampling design, in particular the timing of tagging studies when migratory spawning species show a marked inclination to move in an upstream direction, have biased the results. The team felt that movement is very much cued with the time of year (i.e., prespawning). Downstream movement by way of larval fish drift certainly occurs, and the team felt there is sufficient drift to disperse fish from upstream to downstream areas irrespective of active movement by adults.

Q.5. Is there sufficient evidence to support the idea that recolonization of the Ohio River has occurred and is likely to continue primarily by fish moving from downstream to upstream in the river?

A.5. Big river species can only come in from downstream sources. Other species were from tributary streams. Both sources were important contributors to recolonization of stocks in upstream areas previously impacted.

Q.6. Should attempts be made to reestablish populations of fish extirpated from the upper river in order to have proper hosts available for mussels?

A.6. The OSU Mussel Database indicates that there are adequate fish hosts in the upper river and that is not a limiting factor to mussel recolonization. Although there were some opinions expressed in favor of reestablishment of fish hosts, there were also concerns with regard to ensuring populations are genetically compatible with historical stocks.

4.8.1.3 Summary of Information on Fish Passage

Navigation dams on the Ohio River do not completely block fish movements in an upstream direction. Some fish are able to migrate from downstream to upstream and recolonize now suitable areas from which they were previously extirpated. In addition, fish species from refugia in tributary streams are contributing to recolonization, particularly in uppermost portions of the river. As water and sediment quality, coupled with other habitat characteristics, continue to improve in the upper reaches of the Ohio River, fish populations could be expected to further recover.

Conversely, navigation dams serve to slow fish movements much of the time. While some movement probably occurs during normal lockages, special operations to encourage movements have been shown to increase movements. It appears that the greatest opportunities for upstream movement by fish are under high flow conditions wherein dam gates are lifted out of the water and "open river" conditions exist. Findings of these studies reveal that not all fish species can migrate through dams during periods of high velocity, that there are numerous migratory species of varying size and swimming abilities, and that connectivity was available at all flow conditions prior to the construction of the dams.

The potential for fish passage through the gates of navigation dams is higher for projects along the lower reach of the Ohio River because of design features of these dams. Relative to their tailwaters, their gates sills are submerged. On the other hand, fish passage potential through gates is near zero for some of the dams on the upper reach of the Ohio River because they have "dry sills," well elevated above the water level of their tailwaters even under very high flow conditions.

For replacement navigation structures such as will likely be built along the Emsworth-Dashields-Montgomery portion of the upper river, based on fish passage issues alone, a logical recommendation would be to design the gate sills of the replacement dams to be submerged to the lowest elevation possible. However, there would be a serious negative impact from such a design change. Higher sill elevations promote more efficient gas exchange and reaeration, while dropping the sills to improve fish passage potential would result in depression of DO concentrations in the river.

A cost-effective and easy remedy to this apparent dilemma exists: Fish passage is associated with high flow periods, while most reaeration benefits accrue during summer low flows. Therefore, submerged sill gates can be designed for maximum discharge capacity and fish passage potential during high flows and an additional elevated sill water quality gate can be designed for use during low summer flows. Such a gate arrangement is now being constructed for the Monongahela River L/D 2 replacement dam at Braddock. The Corps' Engineer Research and Development Center (ERDC) in Vicksburg contributed to the hydraulic design of the slope of the sill and the apron at Braddock L/D to maximize the reaeration efficiency of the water quality gate. The two-level gate arrangement should help to prevent the chronic summer low flow water quality problems from submerged sill gates discharges at Opekiska L/D on the Monongahela and at relatively new navigation dams on the Red River. Further, fish passageways should be considered where opportunities exist.

As addressed in the previous Q and A's, navigation dams on the Ohio River will not serve to block the spread of invasive aquatic species, but may delay their spread and allow time for development of preemptive measures.

Although fish movements are somewhat restricted compared to pre-impoundment river conditions, lack of suitable fish hosts does not appear to be a limiting factor to reestablishment of mussel communities in upper reaches of the river. The presence of fish hosts does not mean there are adequate abundances of host species or adequate movement throughout the river to allow for mussel populations to sustain, let alone expand. See CEA Chapter 5 for a more thorough discussion of mussel resources.

4.8.1.4 Conclusions Concerning Ohio River Fish Passage

Both upstream and downstream movements of some fishes occur on the mainstem Ohio River. These movements, however, are more restricted than under un-impounded conditions. Opportunities for fish movement in an upstream direction are greatest under "open river" conditions, which occur seasonally under high flow (e.g., flood) conditions. Fish hosts for mussel glochidia are not limiting reestablishment of mussel communities in upper portions of the river. Special lockage operations are likely to facilitate fish movements. To improve opportunities for year-round fish movement past navigation dams on the Ohio River, special lockage operations should be considered. Further, as future navigational improvements, such as auxiliary lock chamber extensions or lock replacements are developed, fish passage facilities should be considered in designs. Such facilities are most needed at upper river locations where open river conditions do not regularly occur. Plans for fish passage facilities should consider characteristics of target native species and, when possible, make provisions to limit movement by non-native invasive species. Fish passage is a systemic need and will be included as a consideration at all L/Ds as a mitigation need.

4.8.2 Effects of Towboat Operations and Recreational Boating on Fish in Large Rivers

Propellers of commercial towboats can cause abrupt changes in hydraulic patterns, including increased turbulence and water velocities with resulting injury or mortality of adult fish, eggs, and larval stages (Maynord 1990; Hyun and Patel 1991; as cited in Killgore et al. 2000). Field investigations of these effects have been limited, in part because of the difficulty of sampling organisms in turbulent water behind large vessels. Two recent studies prepared for the Corps on the Upper Mississippi River-Illinois Waterway may be applicable to other large river systems, including the Ohio mainstem.

Using fish species that occur in the Mississippi River, Killgore et al.(2000) evaluated mortality of early life stages of fish entrained through water currents induced by a scale model of a towboat propeller placed in a large circulating water channel. During early life stages, fish are particularly vulnerable to propeller impacts because they are fragile and unable to avoid turbulent conditions. Further, high mortality of eggs and young individuals may signal a subsequent decrease in adult recruitment, particularly for species that occur in main channel habitats. The five fishes studied by Killgore and his colleagues – larval shovelnose sturgeon, larval lake sturgeon, eggs and larvae of paddlefish, juvenile common carp, and larval blue sucker – also have been recorded for the Ohio mainstem.

Simulating actual propeller conditions, the study found low or nonexistent mortality of paddlefish eggs, most likely because of the eggs' spherical shape and flexibility. Juvenile carp also experienced low mortality, probably because of protection afforded by their more highly developed organs and more rigid integuments. In contrast, fish in the more fragile larval stage experienced higher mortalities, linearly correlated with increasing propeller velocities and more turbulent conditions that result in differential force (shear stress) across a fish's body. Larval mortalities varied by size and species, with higher tolerances by larger individuals and by species adapted to higher velocity habitats. The study concluded that shear stress created by propellers can be a major source of larval fish mortality. Linear relationships between mortality and shear stress suggest that mortality can be predicted for different towboat configurations and extrapolated to approximate impacts of increased navigation traffic.

The second Mississippi River-Illinois Waterway study, Gutreuter and Vallazza (2002), sampled entrained adult fish by following tows on Pool 26 of the Upper Mississippi and the Alton Pool of the Illinois River. The combined data from 1996-1997 and 2000-2001 yielded entrainment mortality rates for gizzard shad and skipjack herring of 2.52 and 0.13 adult kills/ km of tow travel, respectively. Gutreuter and Vallazza concluded that with high annual tow traffic, even small entrainment mortality rates can yield high estimates of annual losses. Other fish species qualitatively observed as injured by propeller entrainment were shovelnose sturgeon, shortnose gar and black buffalo. An upward-swimming fright response observed in the shovelnose sturgeon may place this typically bottom-dwelling fish at increased risk of entrainment through towboat propellers. Anecdotal evidence from Pool 26 also suggests that some fish are killed during acceleration of downbound tows as they exit locks.

Lowery et al. (1987) and others (cited by Gutreuter and Vallazza 2002) have studied the ability of some fishes to avoid approaching vessels. These results suggest that further research on acoustic emissions of towboats and behavioral responses of channel-dwelling fishes may lead to the development of measures to maximize the avoidance response and thereby minimize the risk of entrainment.

Although recreational boating surveys have been conducted along the Ohio River, such surveys generally have not focused on the effects of recreational boating on fish and their habitats. A 1999 literature review by the North American Lake Management Society (NALMS) emphasizes that impacts of recreational boating on fish and other aquatic life are most pronounced in shallow waters and are compounded by the fact that peak boating activity during the warmer months usually coincides with critical life stages of aquatic organisms in temperate regions. Wave action by high-speed watercraft can disturb or destroy spawning nests and promote shoreline erosion. Suspended sediments churned by recreational vessels in shallow waters not only can smother fish eggs and habitat, but also can damage gills leading to decreased growth rates and lower fish biomass overall. The NALMS' review also cited studies confirming that prolonged use of outboard motors destroys or reduces aquatic macrophytes and invertebrates that are important components of fish habitat. Most studies cited by NALMS focus on lakes and reservoirs and fish species that typically inhabit them. Because scant information exists on the effects of recreational boating on large rivers, it remains a topic ripe for additional research.

4.8.3 Winter Habitat Used by Fishes in the Ohio River

Winter is a critical period in which high mortality occurs in fishes. Many temperate fishes undergo a torpor-like state when exposed to prolonged cold temperatures and short days (Oliver et al.1979; Cunjak 1996; Garvey et al. 1998, and Crawshaw 1984; as cited in Garvey et al.2003). Swimming ability is compromised at low temperatures in many species. Further, given low food availability and energetic costs of maintaining position during winter, fish may seek low velocity habitats to avoid energy depletion. As in other large temperate rivers, winter habitat requirements for fish in the Ohio River revolve around temperature, oxygen concentrations, flow velocities, and food availability. A literature review conducted by Garvey et al. (2003) for ORMSS found that because many Ohio River fish species likely home to the same overwintering locations each year, such areas are important for survival during critical winter periods. In addition during winter, fish may be highly susceptible to vessel-passage induced displacement from velocity shelters. Relatively small velocity changes, such as those that can be induced by vessels, can displace small bluegill and channel catfish from low velocity habitats when water temperatures are low (1 - 4 degrees C) (Sheehan et al. 2000; as cited in Garvey et al. 2003)). If fish are displaced into flowing channels at such temperatures, mortality will probably increase (Bodensteiner and Lewis 1994; as cited in Garvey et al. 2003).

Because the Ohio River extends through mid-temperate latitudes, inter-annual variability in winter temperature may translate to highly variable responses of fish populations to changes in flow velocity and flow direction with navigation. Fish residing at different latitudes within the main channel may be confronted by fundamentally different temperature-dependent challenges that vary among years, as well as by life stage and species. Habitat characteristics affecting winter survival of fish may well vary locally among adjacent pools as well as geographically between the upper and lower reaches of the Ohio River ecosystem. To understand how abiotic characteristics (e.g., latitude, channel morphometry, depth) regulate winter habitat use of critical fish species, Garvey et al. 2003 conducted a two-year, winter survey of a lower pool (Smithland – RM 846 to 918) and an upper pool (Belleville – RM 162 to 204) of the Ohio River. The research was a joint project of Southern Illinois University and West Virginia University.

Species richness (i.e., total number of species sampled) differed between Smithland and Belleville Pools during the two sampling winters. In Smithland Pool, a total of 19 species were sampled each year. Species richness was much higher in Belleville Pool, with AC electrofishing generating a total of 28 species. During both years in Smithland Pool, freshwater drum and blue catfish dominated samples, often comprising > 90% of fishes. In Belleville Pool, freshwater drum were often abundant, but channel catfish was the dominant catfish species. These species typically comprised 80% of fishes sampled, with other species such as gizzard shad being important as well.

Winter habitat use by fishes differed between the pools, as did the types of habitat studied **(Tables 4-7 and 4-8)**. During both winters in Smithland Pool, catch per unit effort (CPUE - number of fish per hour) was higher in sites adjacent to the main channel (i.e., main channel and artificial) than in tributaries. CPUE varied considerably among sites in Belleville Pool, with maximum average catch rates exceeding those in Smithland Pool. Catch rates of fish were higher in tributaries in Belleville than in Smithland Pool. Also,

catch rates of fish in Belleville Pool were higher in sites associated with the main channel in 2003 as compared to other macrohabitats sampled.

TABLE 4-7
Winter habitat types sampled in the Smithland Pool of the Ohio River

Habitat Type	Description
Main Channel	Area extending from shore including the center of the channel.
Island/Backwater	Area between an island and the shore. May be closed at one end of the channel (i.e., creating a flow break).
Artificial Flow Break	Artificial structures such as wing dams and moorings that create relatively deep scour holes; includes lock and dam complexes
Tributaries	Streams that flow into the main channel.

Species richness in macrohabitats of Smithland Pool varied with abiotic factors during both winters. Both tributary and island backwater sites had high species richness at cold temperatures. Further, species richness in tributaries increased with a slight rise in flow rates. When DO concentrations declined below 5 mg/L in Smithland tributaries (which occurred at warm, late-spring temperatures), fish species richness declined. Small, young freshwater drum were associated with tributary sites during winter in Smithland Pool, suggesting that these areas may provide some refuge for early life stages. In Belleville Pool, high catch rates and richness in tributaries during winter were likely due to the low flow rates in these macrohabitats. However, when temperatures in these areas declined below 4 degrees C, fish were more abundant in main channel areas, suggesting that fish leave cold water areas to inhabit relatively warmer but higher flow areas in the river.

TABLE 4-8
Winter habitat types sampled in the Belleville Pool of the Ohio River

Habitat type	Description
Main Channel	Area extending from shore including the center of the channel.
Backwater	Area between an island and the shore without barge traffic.
Island head	Area adjacent to the upstream end of an island.
Island tail	Area adjacent to the downstream end of an island.
Tributary	Area encompassing a tributary mouth and its connection to the main channel.
Embayment	A shallow bay-like area connected to the main channel.
Artificial wing dam	A near-shore area of low velocity created by an artificial barrier.
Deep hole	Dredged or natural scour areas within the main channel or back channel.

Several conclusions and implications applicable to fish sustainability from the study include:

- During both winters and in both pools of the Ohio River, fish assemblages and abundances differed among the winter macrohabitats.

  - In Smithland Pool, habitats adjacent to the main channel appeared to be important for fish during the winter. Particularly, island backwaters and submerged boulders at the channel border were areas that contained large aggregations of fish during cold, winter conditions. Deep scours created by artificial structures (e.g., submerged wing dikes) also provided refuge for fish at cold temperature

  - Tributary macrohabitats in Smithland Pool only provide important winter habitat when temperatures were low and when these areas were connected to the main channel. Tributaries in Smithland Pool are often disconnected from the main channel by a shelf of sediment and debris that may inhibit the passage of fish from the main channel and are not available for fish to access.

- In Belleville Pool, tributaries and an embayment area appeared to play a critical role for wintering fishes. However, these macrohabitats may cool more than the main channel during some winter periods (e.g., as might be expected during a period of snow melt), necessitating the movement of fish into warmer main channel areas. Surface electrofishing of shallow areas adjacent to the main channel revealed that different fish assemblages may be using these areas during winter.

- When fish use main channel habitats during winter, they may be subjected to changes in flow as barges move into their proximity. Fish with impaired swimming ability at cold temperatures (e.g., freshwater drum) may be displaced by changes in flow direction and velocity.

- After barge passage, displacement of water caused flow velocity to increase and a multidirectional flow pattern to occur. Flow rates continued to be affected by barges 15 minutes following passage of the bow. Thus, fish seeking typically low velocity deep water habitats behind river structures may be displaced if low temperatures reduce swimming ability, a pattern consistent with other studies.

- This unique opportunity to conduct parallel research projects in two impounded Ohio River reaches during the same winters provided insight into the potential effects of increased navigation on fish assemblages as follows:

  - Tributary habitats are clearly important to wintering fish, and reduced connectivity in Smithland Pool likely compromises the success of many species. Improved connectivity, perhaps through dredging at confluences, may improve winter success of fishes in this pool. Higher species richness and greater tributary use by fishes in Belleville Pool suggest that connectivity may not be problematic in that pool.

  - Many fishes such as channel and blue catfish use sites adjacent to the main channel in Smithland Pool. Similarly, channel catfish use the main channel in Belleville Pool.

  - Artificial sites such as wing dikes in Smithland Pool create scours that are used by river fishes. Artificial sites may be subject to displacement by barges, although this potential needs further exploration before definitive conclusions could be drawn.

  - Island backwater areas appear to be particularly important for fishes during winter. These areas provide flow breaks and are relatively sheltered from barge activity (i.e., areas in which barges do not traverse but can be affected by flow and elevation changes as barges transit in the river).

In the Ohio River mainstem, quantity and availability of winter refuge may well determine the relative survival and abundance of resident fish populations. River habitat

management that enhances/maintains accessibility to these areas should be beneficial to wintering fish in the Ohio River.

4.8.4 The Navigation Predictive Analysis Technique (NAVPAT) Model

Since the 1980s, the Corps and interested resource agencies have conducted substantial research on the effects of commercial navigation on habitats in large river systems such as the Mississippi, Ohio, and Illinois. The potential for tows to disturb bottom substrates and interfere with fish feeding and reproduction are of particular concern. Over the past 20 years, the Louisville District of the Corps has developed the Navigation Predictive Analysis Technique (NAVPAT) model to assess potential incremental biological effects of various navigation planning scenarios. The goal of NAVPAT is to provide quantitative results, which can assess positive or negative changes in available fish habitat quality for a specific area of a river cross-section (called a "cell") or for an entire reach of river. In general, NAVPAT links tow movements to possible biological effects. The NAVPAT model consists of four primary input components:

- river reach characteristics – including information describing multiple reaches of a river which share basic aquatic habitat conditions; i.e., reaches with similar bathymetry, substrate, depth, and velocity profiles
- economic scenarios – including data on various navigation forecasts, as well as data simulating various tows by length, width, speed, travel direction, horsepower, propeller dimensions, and other measurable characteristics
- physical forces – including information about several types of hydraulic forces generated by tows moving through a waterway, and
- biological species life-stage models – including fish life-stages selected to represent guilds of all major habitats and life stages in a river system.

In consultation with the USFWS, the Corps - Louisville District has incorporated 15 life-stages of fishes into NAVPAT as explained in **Table 4-9**.

TABLE 4-9
Fish Life Stages Selected for Ohio River NAVPAT Model

Fish Species	Life Stages/ Functions of Concern	Rationale for Species Selection	Potential Impacts of Concern
Emerald shiner	Spawning, fry	Represents open water spawners in areas of lower ambient current velocity and fry with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of nonadhesive eggs as water velocity increases with tow passage 2) Destruction of fry caused by entrainment through propellers or associated pressure and turbulence

Fish Species	Life Stages/ Functions of Concern	Rationale for Species Selection	Potential Impacts of Concern
Paddlefish	Spawning, larval stages	Represents open water spawners in areas of moderate ambient current velocity and fry with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of adhesive eggs as water velocity increases wit tow passage 2) Destruction of fry caused by entrainment through propellers or associated pressure and turbulence
Freshwater drum	Adult food, egg/larval stages	Represents open water spawners in almost any portion of a river and adults that feed on organisms found in bottom sediments	1) Destruction of egg/larval stages caused by entrainment through propellers or associated pressure and turbulence 2) Dislodgment of substrates caused by water velocity from tow passage
Sauger	Spawning, larval stages	Represent spawners in relatively high ambient current in areas with coarse substrate and larvae that move to areas of lower ambient current velocity with very limited mobility to avoid tow traffic	1) Dislodgment from bottom substrates of adhesive eggs as water velocity increases with tow passage and/or abrasion of eggs due to substrate scouring 2) Destruction of larvae caused by entrainment through propellers or associated pressure and turbulence
Channel catfish	Young-of-year	Represents species whose young feed primarily on aquatic insects in shallow water with low ambient current velocity	Dislodgment of substrate caused by water velocity from tow passage which could reduce the availability of aquatic insects on which these fish feed
Black crappie	Spawning, fry food, juvenile food and adult food	Represents nest spawners in shallow water and fry, juveniles, and adult that feed significantly on benthic aquatic insects in predominantly different portions of a river channel throughout their lives	1) Dislodgment of eggs from nests because of water velocity increases with tow passage and vulnerability of eggs to predation 2) Disturbance of substrate that could deposit on eggs and smother them 3) Disturbance of substrate that could reduce the availability of aquatic insects on which these fish feed

Fish Species	Life Stages/ Functions of Concern	Rationale for Species Selection	Potential Impacts of Concern
Spotted bass	Spawning, juvenile food	Represents nest spawners in moderate depth water with coarse substrates and juveniles that feed significantly on small benthic invertebrates	1) Dislodgment of eggs from nests because of water velocity increases with tow passage and vulnerability of eggs to predation 2) Disturbance of substrate that could reduce the availability of aquatic insects on which these fish feed

SOURCE: U.S. Army Corps of Engineers, Environmental Effects of Commercial Navigation Traffic – McAlpine Lock and Dam Project, NAVPAT and QUEPAT (not dated).

Although refinements to NAVPAT continue, the model can be used to evaluate environmental effects on a given life stage for a given traffic scenario and, in fact, has been applied to studies near Olmstead L/D and McAlpine L/D. Life history, river stage, discharge, and water temperature data are sufficiently available to apply NAVPAT to the time period when a particular species' life stage may be vulnerable. The developers of NAVPAT emphasize, however, that while it is a useful tool for evaluating traffic-induced impacts, NAVPAT should not be extrapolated to other human activities on or in the river. It remains unclear whether verification of NAVPAT results could be made by long-term monitoring, primarily because of the potential cumulative impacts of other human activities that could be difficult to distinguish from impacts of commercial navigation traffic.

4.8.5 Effects of Cooling Water Intake Structures on Fish

Large volumes of cooling water are withdrawn from the Ohio River to cool various industrial facilities, including stream electric power plants, pulp and paper makers, chemical manufacturers, petroleum refiners, and manufacturers of primary metals such as iron, steel, and aluminum. Cooling water intake structures cause damage to fish and other aquatic organisms that are pulled (entrained) into industrial cooling systems. Once entrained, organisms may be killed or injured by heat, physical stress, or chemicals. Larger organisms, including fish, may be killed or injured when they are trapped against screens (impinged) at the front of an intake structure.

Section 316(b) of the CWA requires that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts. In accordance with new and proposed regulations related to §316(b), USEPA recently evaluated entrainment and impingement rates at nine power plants on the Ohio mainstem between RM 53.9 and 560 (USEPA 2002). The main fish species the study found to be at risk were emerald shiner, freshwater drum, gizzard shad, sauger, white bass, white crappie, and white sucker (USEPA 2002). Several of these species have floating (pelagic) eggs or larvae that make them more vulnerable to intake damage.

When extrapolated to all cooling water intakes on the Ohio River, the results of the study indicated that impingement at all power facilities along the Ohio River causes the mortality of approximately 11.6 million age 1 equivalent fish per year, or 15,500 pounds of

lost fishery annually. The entrainment results indicated that all facilities combined cause the mortality of approximately 24.5 million age 1 equivalent fish per year, representing nearly 40,000 pounds of lost fishery yield annually. However, because the study used limited 1977 data from a period when water quality in the river was worse and fish biomass was probably lower than it is presently, U.S.EPA suggests that the results probably underestimate current entrainment and impingement losses along the Ohio mainstem, consequently, underestimating the benefits of new and proposed regulatory action.

Lohner et al. (2000) and Perry et al. (2001) report on modeling exercises to assess 316(b) impacts on Ohio River fish populations using more recent data from the long-term Ohio River Ecological Research Program and ORSANCO electrofishing. In six of 22 scenarios of fish species and river pool, the projected fish population changes due to impingement and entrainment were greater than the expected natural variability of existing populations, consequently, indicating possible adverse environmental impacts (Perry et al.). The significance of these findings is obscured by the combination of other abiotic (e.g., river flow, water quality, habitat quality) and biotic factors (e.g., predation, exotic species, competition) to which fish populations respond. Further §316(b) studies at several power plants along the Ohio River are anticipated as additional phases of the 316(b) program are implemented by USEPA in the coming years.

4.9 INTERACTIONS WITH OTHER VECS

Because of their diverse ecological niches and their importance in river recreation and its related economy, fish interact with almost every VEC considered in this CEA. Unlike mussels, which have limited mobility, fish are highly mobile and widely distributed throughout the Ohio mainstem. One of the strongest links occurs between fish and water and sediment quality. Fish species composition, abundance, and condition are all excellent indicators of water and sediment quality. As documented in the discussion on baseline conditions, many fish species that took refuge in the lower Ohio River during the worst decades of pollution have recovered and moved upstream. Consequently, densities, biomass, and fish community diversity have increased measurably as water quality has improved. Sport fishing also has improved and increased in popularity as fish populations have increased. Increased sport fishing has enhanced the perception of the river's recreational value and, in turn, has benefited local economies. Despite ongoing improvement in water quality, however, fish consumption advisories remain in effect for a number of Ohio River fish species. (See Chapter 8, **Health and Safety**)

Fish and mussels are very closely linked aquatic groups with generally mutually beneficial interactions. Mussels are an important food resource for certain bottom-dwelling fishes, including suckers and catfishes. Conversely, fish are critical to mussel distribution, because they serve as hosts for the immobile glochidial (larval) stage of mussels. The recently introduced black carp may be an exception to the beneficial interaction between fish and mussels as it has the potential to feed on already vulnerable native mussels.

Fish also are conspicuous components of riparian ecosystems. Wetlands and embayments along the Ohio mainstem provide vital spawning and nursery areas for many fish species. During winter, lower current velocities and warmer temperatures in these

habitats offer refuges to fishes of all age groups. Waterbirds, including migratory species, rely on fish in riparian areas as an important food source. Islands, another riparian habitat beneficial to fish, add to habitat diversity within the mainstem, while islands' back channels offer fish quieter refuges from the currents and traffic of the open channel.

As was underscored in the section titled "Studies Concerning Specific Impacts on Fishes," a broad spectrum of human activities affect fish in the Ohio mainstem. Direct impacts include obstruction of fish movement, movements of commercial and recreational vessels, damage to fish habitats through removal or sedimentation of bottom substrates, and impingement or entrainment in cooling water intake structures. The following section discusses an array of floodplain and in-water activities that lead to changes that can reduce or impair fish habitat and contribute to point and nonpoint source pollution.

4.10 RELEVANT ACTIONS AFFECTING FISH

This analysis of relevant actions affecting fish attempts to integrate ecological processes related to species, habitats, and ecological services on a system level. As indicated previously, fish respond to multiple interrelated factors, making it difficult to examine any action or ecological process in isolation. While acknowledging that actions and ecological processes overlap and interact in complex ways, we have aggregated RFFA effects on fishes into five major groups:

1) habitat changes (Ha) – including the integrity of critical habitats, patterns and connectivity of habitats, and structural complexity of habitats
2) changes in disturbance regimes (DR) – including the alteration of conditions to which species and ecosystems have adapted over a long period of time
3) changes in hydrologic patterns (Hy) – including alterations to water connections that influence biodiversity and ecological integrity
4) effects on ecological services (EcS) – including impacts on nutrient cycling and purification services that break down toxins and transform soils and sediments, and
5) changes related to populations (P) – including impacts of exotic species, population dynamics, and genetic diversity

Of 87 actions included in the RFFA matrix, 32 actions were ranked "high importance" and 29 actions were ranked "medium importance" for fish. **Table 4-10** lists all high and medium RFFAs, indicates if the action is generally beneficial (+) or detrimental (-), and lists the action's effects according to the key above.

TABLE 4-10.
RFFA Cumulative Effects Matrix for Fish

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Effects on Fish	Impor-tance[5]	Ecological Processes Affected[6]
Navigation Investment Actions						
Lock Extensions/New Locks/ Replacement or Rehabilitation	A	H	SL, E	-	M	Ha, DR, Hy
L&D operation and maintenance	A	H	SL, E	-	M	All
Non-structural navigation improvements	A	H	SL, E	+	H	Ha
Dam replacement and rehabilitation	A	H	SL, E	-	H	All
Other Corps Actions						
Channel dredging/dredged material disposal	A	H	SL, E	-	H	Ha, Hy, ES
Flood damage reduction projects						
levees/floodwalls	A	L	E	-	H	All
dry dams, other projects off mainstem	A	M	E	-	M	All
channel modifications	A	H	E	-	M	All
Nonstructural measures (e.g., relocation)	A	H	E	+	H	All
Emergency streambank stabilization (Sec. 14)	A	H	SL, E	-	M	Ha, Hy
Modification of Corps structures for environmental improvements (Sec. 1135)	A	H	E	+	H	All
Environmental restoration of aquatic ecosystems (Sec. 206)	1,2	H	E	+	H	All
ERP Projects - 5 categories	A	H	E	+	M	All
Port development (Sec. 107) and maintenance dredging	A	H	SL, E	-	M	All
Pool maintenance	A	H	E	-	H	All
"But for" Actions						
Commercial Navigation						
barge queuing	A	H	SL, E	-	M	Ha, P
fleeting areas/barge storage	A	H	SL, E	-	M	Ha
terminals	A	H	SL, E	-	M	All
multi-modal sites	A	H	SL, E	-	M	All
increased traffic	A	H	E	-	H	Ha, P
dispersed barge traffic	A	H	E	-	M	Ha, P
accidents/spills	A	H	E	-	H	Ha, P
Instream sand and gravel mining	A	H	SL, E		H	Ha, Hy, P
Coal utilities	A	H	SL, E	-	M	Ha, Hy, ES, P
Other coal industries	A	M	SL, E	-	M	Ha, Hy, ES, P
Hydropower on dams	A	H	SL, E	-	H	Ha, P
Industrial users, excluding coal-related	A	H	SL, E	-	M	Ha, Hy, P

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Effects on Fish	Impor-tance[5]	Ecological Processes Affected[6]
Actions by Others						
Public lands acquisition and management	A	H	SL, E	+	M	All
Floodplain development						
residential	A	H	E	-	M	All
commercial	A	H	E	-	M	All
industrial	A	H	E	-	M	All
Crossings						
bridges	A	H	SL, E	-	M	Ha, Hy ES, P
utility	A	H	SL, E	-	M	Ha
industrial	A	H	SL, E	-	M	Ha
Riverbed crossings	A	H	SL, E	-	M	Ha
Marina development & operation	A	H	SL, E	-	M	Ha, Hy, ES, P
Water-based recreation:						
fishing	A	H	E	-	H	Ha, P
Agriculture	A	H	R	-	M	Ha, Hy, ES, P
WWTP discharges						
municipal	A	H	U	-	H	Ha, P
industrial	A	H	U, R	-	H	Ha, P
onsite systems	A	H	R	-	H	Ha, P
Stormwater discharges	A	H	U, R	-	H	Ha, P
Brownfields redevelopment	A	H	U	+	M	All
Hazardous waste sites	A	H	SL	-	H	All
Natural Climatic Events						
floods	A	H	E	+	H	All, especially DR
droughts	A	H	E	+	H	All, especially DR
severe storms	A	H	E	+	H	All
Regulatory Environment						
Phase I & 2 NPDES program	A	H	SL, E	+	H	Ha, Hy, ES, P
TMDLs	A	M	E	+	H	Ha, P
Site remediation	A	M	SL, E	+	H	All
More stringent quality standards for environmental media	A	M	E	+	H	Ha, ES, P
Pollutant source control	A	M	E	+	H	Ha, ES, P
Wetland Mitigation Banking	A	M	SL	+	H	All
Carbon sequestration	A	M	R	+	H	ES, P
Farmland preservation	A	M	R	+	H	All
Corps permitting programs	A	H	SL, E	+	H	All
Small navigation projects	A	H	SL, E	-	M	All
ORSANCO monitoring program	A	H	E	+	M	Ha, ES, P
Spill response	A	H	E	+	M	Ha, ES, P
ESA (Endangered Species Act)	A	H	E	+	H	All

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Effects on Fish	Impor-tance[5]	Ecological Processes Affected[6]
Environmental sustainability practices	A	M	E	+	H	All

Table Notes:

[1] Reasonably Foreseeable Future Actions

[2] Time period in which the RFFA may occur:
1 = within 10 years 2 = in 10 - 25 years 3 = in 25 - 60 years A = applicable to all time periods

[3] Occurrence probability or likelihood RFFA will happen:
H = high M = medium L = low

[4] Location or setting on river where RFFA is expected to occur:
U = upper (Pittsburgh - Huntington) M = middle (below Huntington - Louisville)
L = lower (below Louisville - mouth) E = along entire length of river
SL = selected locations, e.g., locks and dams U = urban setting R = rural setting

[5] Importance of RFFA:
H = high M = medium L = low

[6] Ecological Processes Affected:
Ha = habitat changes that affect critical habitats, patterns, connectivity and complexity
DR = disturbance regimes; includes alterations of conditions to which species have adapted over long periods of time
Hy = hydrological changes to the channel and/or river floodplain
EcS = ecological services; includes impacts on nutrient cycling and purification services that affect toxins, soils and sediments
P = population changes; includes impacts of exotic species, population dynamics and genetic diversity

The ecological processes listed above have been adapted from USEPA - Office of Federal Activities. 1999. Considering ecological processes in environmental impact assessments (es.epa.gov/oeca/ofa/eco/99.html).

4.10.1 Actions Contributing to Habitat Changes (Ha)

This group includes

- Actions that physically alter fish habitats by direct damage or removal of bottom substrates, spawning areas and/or bottom-dwelling organisms upon which fish feed. The Corps, navigation industry, power industry, and other river users undertake these actions.

- Such actions also may indirectly alter fish habitats by limiting prey visibility or blanketing spawning areas with sediment. Channel maintenance dredging and in-stream sand and gravel mining, both rated of high (H) importance, exemplify actions with both direct and indirect impacts on fish habitat.

Channel maintenance dredging (H) involves the removal and disposal of sand and gravel deposits from the navigation channel of the Ohio River to maintain a nine-foot depth. Mussels and other bottom-dwelling aquatic organisms upon which fish feed also may be removed during dredging. For most extended reaches of the Ohio River, channel maintenance dredging is an ongoing activity. Past practices in all but the upper 120 miles of the river have generally utilized in-stream disposal of dredged materials. This practice alters fish habitat through the redistribution of sediments, which may cover eggs and spawning areas of fish that prefer clean gravel substrates (lithophils) and interfere with fish

feeding and respiration. Dredging also may resuspend contaminants, increase concentrations of plant nutrients, lower or increase photosynthesis, and increase biological oxygen demand (Watters 1999), causing adverse effects throughout food webs. The elimination of suitable habitat, destabilization of bottom substrates, and the creation of deep pools also can inhibit recolonization of dredged areas by fish and other aquatic life (Kanehl and Lyons 1992). Conversely, carefully planned in-water placement of dredged material can effectively restore aquatic habitat. Recommendations for mitigating the adverse impacts of channel dredging include:

- restricting dredged areas to the minimum required to maintain the navigation channel,
- conducting long-term monitoring of aquatic habitats where dredging has occurred and/or continues,
- evaluating land disposal of dredged materials, and
- using dredged materials to create new sandbars, islands, or riparian habitat beneficial to fish and other aquatic life (e.g., using structural fill for streambank restoration projects).

Ongoing commercial in-stream sand and gravel mining (H) also involves the removal of sand and gravel deposits from the river and their subsequent transport to land. Such operations are numerous along the Ohio River, as the navigation system makes river-based extraction and transportation of dredged aggregates economical. In the Corps' Huntington District alone (RM 126-440), 20 river reaches, ranging from 0.5 to 4.2 miles, have permits for sand and gravel dredging. Environmental concerns related to commercial sand and gravel dredging include possible mobilization of contaminants, turbidity plumes, removal of shallow water habitat, modification of substrate particle size, adjacent bank stability, alluvium aquifer quality, decreased bathymetric diversity, creation of deep holes in the channel which may become anoxic during summer season low flow periods, and attendant adverse impacts of fish, mussels and other aquatic life (USACE 1992 and 2002). Like channel maintenance dredging, commercial dredging potentially results in the disturbance and/or removal of fish habitat and the redistribution of sediments, which may cover substrates preferred by fishes and interfere with feeding and other metabolic processes.

Concerns and potential impacts vary along the length of the river. All three states which regulate commercial sand and gravel dredging on the Ohio River (Pennsylvania, West Virginia, and Ohio) have established setbacks in their permits, or certified setbacks in Corps' dredging permits, to protect resources from adverse dredging impacts. The percentage of cobble and coarser gravel, versus finer gravel and sand in the riverbed, tends to decline in a downstream direction; the persistence of dredging impacts appears to be related to substrate sizes. For example, the Kentucky Division of Water (KDOW) has observed that except for direct disturbance of mussel beds, the impacts of commercial dredging tend to be relatively ephemeral, and 50 to 60 feet deep dredge holes may be completely filled in and restored within a period of only a few years. In contrast, along the upper Ohio River in West Virginia and Pennsylvania, where the substrate of the river is generally coarser and less mobile, dredging induced changes in the bathymetry of the channel and subsequent impacts to habitat tend to be much more persistent, if not essentially permanent. Historical dredging, before the establishment of permit setbacks, in

many areas occurred from bank to bank, eliminating substantial areas of shallow water habitat

Construction of lock chamber extensions (M) also can require dredging and excavation in the Ohio River which could result in destruction, partial loss, or siltation of existing fish habitat in proximity to the construction area. As previously described, dredging would temporarily increase turbidity and suspended solids and potentially release contaminants found in the sediments, though elutions of worst case contaminated sediments from the upper Ohio River failed to release priority pollutants (USACE 1982 and 1989). Increased sediments in the water column would harm the predatory ability of sight-feeding fishes including many sport species. Construction also would require placement around the foundations of extended walls of fill consisting of concrete, rock and earth (removed from the existing structure during demolition.) Dewatering of lock chambers to install additional filling/emptying systems would temporarily increase turbidity in the water column. Unlike channel dredging, construction of lock chamber extensions would be confined to selected locations with minimal occurrences over the study period.

On land, construction of lock chamber extensions would require establishment of parking and maintenance areas for equipment, a lay-down yard for materials, an onsite-disposal area for excavated materials, and some earthwork where portions of the new lock chamber connect with the riverbank. These activities would require clearing of vegetation with potential surface runoff and soil erosion that could result in siltation of fish habitat with attendant adverse effects on spawning, feeding, and respiration.

Barge queuing upstream and downstream of locks and dams would be expected to increase during temporary closures of main and/or auxiliary chambers, if lock chambers are extended. Queuing would create turbidity, mortality of eggs and larval fish, and potential damage to fish spawning beds, mussel beds, and other shoreline habitats while barges await lock passage.

The potential extent of impacts during all aspects of lock extension would vary at construction locations and in queuing areas depending upon the quality of fish habitat. Several actions, however, could be taken to minimize or mitigate impacts including:

- Installing mooring facilities that restrict queuing tows to the navigation channels, thus avoiding direct physical damage to bottom substrates.
- Keeping barges away from sensitive aquatic habitat, including mussel beds, by utilizing various traffic management measures that would reduce queuing (e.g., use of helper boats, lock scheduling with remote mooring, queuing fees/penalties, etc.).
- Installing turbidity curtains to surround construction areas.
- Using environmentally acceptable fill materials.
- Scheduling construction to minimize in-river activities.
- Using dewatering techniques that minimize suspended solids in the water column.
- Implementing erosion control plans that emphasize phased clearing, containment of soils, water detention, and temporary reseeding of cleared sites followed by timely permanent revegetation.
- Creating new side channel habitats with continuous flow and suitable substrate below dams.

- Disposing of dredged materials in a way that either does not affect fish and other aquatic life or creates new habitat.

Chapter 5, Mussels, lists additional measures to protect mussel beds, an important food source for fish.

Barge queuing (M) during normal commercial navigation and its attendant turbidity effects and potential physical damage to fish and habitats would be reduced during normal navigation operations, as a result of increased lock capacity and decreased lock maintenance events. However, barge fleeting and storage (M), which also may cause direct damage to fish habitat and mussel beds, would not be relieved by lock expansions. In fact, barge fleeting and storage areas would be expected to increase in proportion to commercial traffic. Expansion of such facilities may result in temporary riverbed and/or land-based impacts during construction and installation. Using BMPs for sediment and erosion control and avoiding construction of mooring facilities within or adjacent to sensitive aquatic habitats, such as fish nursery areas or mussel beds, would help minimize impacts.

The ongoing commercial use of lock and dam facilities requires periodic upkeep, maintenance and operation (H). This RFFA includes major and minor repairs of both existing primary locks and auxiliary locks. As existing locks age, the need for such repairs become more frequent. Past experience with Ohio River navigation structures indicates the frequency of repairs will generally increase as locks age and in proportion to increases in commercial traffic on the Ohio River. For the 60-year ORMSS study period, scheduled repair events are expected to occur on an average of once every five years for each lock and dam project (USACE 2000).

Impacts on fish and their habitat vary depending upon the location and extent of each lock repair event. Dewatering of lock chambers, establishment of areas for equipment, parking and materials, and barge queuing caused by delays at locks would all potentially impact fish near the work area. These impacts could be lessened through the corresponding actions listed under lock chamber extension in the previous section. Unlike lock extensions, maintenance and repair activities are not expected to require disposal of significant quantities of dredged or excavated materials.

Maintenance and repair events occur with or without lock extensions. Completion of lock extensions or lock additions, however, can reduce repair activities and associated impacts to fish and other aquatic life in three ways:

- It may be feasible to schedule each construction project to eliminate one complete auxiliary chamber repair event or major rehabilitation that would otherwise have been necessary.
- Each extension creates a lock in new condition, allowing for a longer time interval between the auxiliary chamber repair events.
- Finally, the original full sized locks will be used less, since total lockages can be shared equally between two full sized locks allowing for a longer time between main chamber repair events (USACE 2000).

Fewer repair activities lead to reductions in queuing, especially important in the more ecologically sensitive tailwater areas subject to queuing of tows bound upstream. If locks are extended, the impacts on fish directly attributable to maintenance and repair activities are reduced in proportion to the expected reduction in repair activity. Effects from major lock rehabilitation would be similar to those of repairs, but would likely occur over longer time periods.

Whether or not locks are extended, continuing operation of existing locks and dams (rated high) along the Ohio River will have ongoing effects on the composition of fish communities. These effects include siltation, modification of current direction and velocities, downstream scour that can affect reproduction and feeding, and restrictions on movements of fishes that limit genetic diversity (and, therefore, decrease population resiliency) along the river's longitudinal gradient. Further, the continuing operation of existing locks and dams dampens flood cycles, thus interfering with the river's natural disturbance regimes.

An infrequent action with potentially significant impacts on fish is dam replacement and rehabilitation (H), which differs from rehabilitation of lock chambers. While the timing of rehabilitation projects is subject to numerous variables, this activity primarily corresponds to the useful life cycle of a dam. Of the 20 dams currently on the river, 6 have been rehabilitated in the past two decades, at an average age of 60 years following their initial construction. Assuming a life cycle of 60 years, all the dams currently on the Ohio River may require major rehabilitation or replacement during the 60-year cycle of the study period. Impacts related to fish from dam rehabilitation projects would be similar to construction site impacts described previously for lock extension projects. The activities would require similar temporary impacts for construction parking and laydown yards and would likely entail similar needs for the disposal of dredged materials.

Port development and maintenance (M) is another activity with potentially adverse direct impacts on fish habitat and food supply. Use of turbidity curtains to limit downstream siltation is among measures that can mitigate such impacts. Both the Corps and the private sector undertake Port development and maintenance. Development of new terminals and multimodal sites (both rated M) associated with commercial traffic would be expected to further impact fish by scouring of bottom substrates and mortality of sensitive life stages entrained by commercial vessels using the ports. Strict adherence to permit conditions (Section 10, 404 and state 401 certification) would help to minimize these impacts, but would have a lesser effect on continued use of terminal facilities.

Recreational activities, especially the development and maintenance of marinas and boat launch ramps and other support facilities, also can directly impact fish habitat in the Ohio River. Analyses of Corps' navigation charts from 2003 indicated a total of 394 marinas and launch ramps along the Ohio River mainstem, as compared to 356 shown on 1974 navigation charts. For both time periods, the largest number of such facilities occurred in the Louisville District (RM 436-981). Potential impacts of marina development include direct elimination or encroachment on fish habitat and erosion and resultant sediment damage to feeding and spawning areas, unless turbidity curtains or other containment procedures are used during construction. Marinas and related facilities tend to be concentrated in embayments and can be found throughout the floodplain, although marinas concentrate somewhat in proximity to urban areas. Embayments comprise a very

limited resource within the Ohio River floodplain and are especially valuable as fish spawning areas and nurseries for young fish. Additional concerns are related to dredging activity within embayments that is generally required to maintain accessibility to marinas and launch ramps. The expected continued growth of marinas and associated dredging of embayments will displace ecological attributes of embayments, including fish and benthic habitat, presence of macrophytes, and other features that add beneficial structural complexity and diversity to aquatic systems.

Other facilities supporting boating and non-boating activities include urban or rural riverfront parks, riverfront hotel/restaurant complexes, and casino boat/resort complexes. Virtually all recreation infrastructure along the Ohio River has been built in relation to and is dependent upon continued maintenance of the existing system of navigation pools. Construction of these facilities can temporarily increase sediment loads and affect fish habitat, can permanently alter hydrological connections with the river floodplain, and can eliminate riparian habitats that fish may use for spawning and nursery areas.

Because industrial discharges (H) to the Ohio River are now highly regulated under NPDES permitting compared to the pre-NPDES era, potential fish impacts related to industrial activities, coal utilities and other coal-related industries (both M) along the river primarily focus on transfer of potentially harmful materials and maintenance of port/docking facilities. Coal transport alone currently accounts for more than 55% of all barge traffic on the Ohio River and is projected to account for a large percentage of traffic for the foreseeable future. Because of the coal industry's prominence, the associated potential impacts on mussel beds and other habitats from barge activities and spillage of coal fines and other harmful substances are particularly important. Contaminated sediments from past industrial pollution or landfill materials also impair fish habitat. Such contaminants are most prevalent in the heavily industrialized upper river.

Fish communities have been affected by the loss of riparian habitats and hydrological connections along the Ohio River, especially near urban centers where widespread floodplain development has occurred. Floodplain ordinances, government programs and other constraints, however, have limited residential, commercial, and industrial development in the Ohio River floodplain in recent years. Nevertheless, all types of development are rated medium because some floodplain development is expected to continue throughout the study period. Possible impacts related to fish and other aquatic life include increased erosion and attendant siltation during construction and increased stormwater runoff and associated pollutants as impervious surfaces, such as driveways, parking lots, and roof tops increase. The implementation of the Phase 1 and 2 NPDES program (H) over time, however, should moderate stormwater impacts.

Riverbed crossings (M) that convey water or energy related materials frequently intersect the Ohio mainstem. The 1987 navigation charts for the Ohio River showed 282 riverbed crossings. When such lines are laid beneath the river, they directly damage fish and other aquatic habitats and can cause temporary downstream siltation. Because dredging is prohibited from occurring in the vicinity of crossings, some studies have speculated that these crossings may inadvertently protect mussels and other benthic organisms upon which fish feed. Other studies, however, may have suggested long-term habitat damage due to continued scouring of fill material within the crossing.

Corps permitting programs (H) are important because they are designed to regulate several activities related to potential fish habitat impairment. In addition to the Corps permitting program are state administered water quality certifications (§401 Clean Water Act). Corps programs regulate discharge of dredged or fill material into waters of the United States (§404 Clean Water Act), and construction of wharves, piers and other physical obstructions in navigable waters (§10 of the Rivers and Harbors Act of 1899). The Corps permitting programs potentially benefit fish and other aquatic life by providing habitat protection in waterways. Management of permitting programs, however, also must account for cumulative effects of permitted facilities, which can affect fish, mussels, and other aquatic resources.

Actions contributing to changes in fish habitat are of increasing concern to fisheries managers and aquatic biologists. The recently launched National Fish Habitat Initiative is a strategy aimed at focusing national attention and resources on common priorities to improve the quality of aquatic habitats. More information on this initiative and its indicators of habitat quality is found in Chapter 13, Adaptive Management.

4.10.2 Actions Contributing to Changes in Disturbance Regimes (DR)

Floods, droughts, severe storms, and earthquakes are natural disturbance events occurring along the Ohio River mainstem to which ecosystems and species have adapted over long periods of time. Such events occur with some regularity and result in significant changes in ecosystem structure and composition, including changes to fish communities. The natural disturbance regime of an ecosystem refers to the type, magnitude, and frequency of disturbances that would occur within the landscape in the absence of human activities (USEPA 1999). Floods, droughts, and severe storms are rated high in **Table 4-10**. Earthquakes are not included in **Table 4-10**; they are rated low because of their relatively low magnitude and frequency in the region. It should be noted that a high priority need identified during the ES workshops was to allow hydrologic regimes to mimic natural events such as extreme floods and droughts.

Flooding and severe storms redistribute dissolved and particulate organic materials throughout river channels and adjacent floodplains, including the transport of small and large woody debris that influences aquatic food webs and fish habitat. Because the dams of the Ohio mainstem were designed primarily for navigation instead of flood control, they have a negligible impact on natural flood regimes. A countervailing influence, however, has resulted from an increase in impervious surfaces in developed areas of the floodplain, leading to increased runoff and flashiness of urbanized streams during storms, which in turn causes flooding in the mainstem.

By detaining floodwaters, off-mainstem flood control projects (M), contribute to modification of the natural flooding cycle. Conversely, natural drought effects are lessened by scheduled low-flow augmentation releases of water from reservoirs located along tributaries to the Ohio. Channel modifications designed to reduce flooding (M) also affect flow patterns and natural disturbance regimes.

4.10.3 Actions Contributing to Changes to Hydrologic Patterns (Hy)

Changes to hydrologic patterns are closely linked to changes in disturbance regimes and habitat and include alterations to water connections that influence biodiversity and ecological integrity

As discussed in other chapters, one activity frequently stimulates another, compounding negative impacts. Floodplain development, for example, can create a demand for flood damage reduction structures such as levees (H) and floodwalls that, subsequently, cause loss of floodplain habitat and severing of hydrologic connections. By altering connections between a main channel and riparian areas, levees eliminate and block access to potential fish spawning and nursery areas and restrict the transport of organic materials between riparian areas and the Ohio River mainstem.

In contrast to levees, nonstructural flood control measures (H) can help restore hydrological function and connections. Examples of such measures include relocation of housing and businesses out of floodplains and installation of vegetative buffer/filter strips along river corridors. Filter strips have the added benefit of helping to remove sediment and nutrients from runoff before they reach the river.

Land and channel impacts contributing to changes in hydrologic patterns occur during bridge construction, redesign, or replacement (M). This action is rated medium because it is expected to be a relatively infrequent occurrence during the study time frame. Bridges potentially affect fish and other aquatic life because of erosion and siltation during construction and possible long-term alterations of flow patterns, which in turn can cause velocity changes and silt deposition affecting reproduction and metabolic processes. Drastic flow alterations caused by bridges can lead to the disappearance of entire islands as occurred at Baker Island (formerly located at RM 49.5). Similarly, construction of the Interstate 79 bridge piers near Pittsburgh in the 1970s quickly led to the scouring away of Hughey Island a short distance downstream.

Ecosystem Restoration (ER) projects (M), including restoration of wetlands and riparian habitats, have potential to restore ecological functions and services, including reconnecting the floodplain to the river. Fish could further benefit from ER projects that include water quality improvements among project objectives. Brownfields redevelopment (M) and remediation of contaminated sites (H) in riparian areas likewise are actions beneficial to restoration of hydrologic connections when such sites are returned to more natural soil and vegetation conditions. When redeveloped for commercial or industrial use, such sites also may spare conversion of other green space within the floodplain. The Phase 1 and 2 NPDES program (H) also is a beneficial regulatory action because it manages stormwater runoff to prevent further damage to hydrologic connections and promotes innovative ways to manage runoff. These actions and others that reduce sediment input or reverse severing of hydrologic connections improve conditions for fish and other aquatic life.

4.10.4 Actions Affecting Ecological Services (EcS)

Actions included in this category have impacts on nutrient cycling and on purification services that break down toxins and transform soils and sediments. Nutrient

cycling refers to the processes by which elements such as nitrogen, phosphorus, and carbon move through an ecosystem while purification services are the result of effective nutrient cycling.

Most actions affecting ecological services occur within the floodplain. An in-stream activity considered of high negative importance, however, is channel dredging (H) because of its potential to resuspend contaminants, increase concentrations of plant nutrients, lower or increase photosynthesis, and increase biological oxygen demand (Watters 1999), causing adverse effects throughout food webs. While results of studies by DeLaume et al. (1976) suggest that sediments can be a stable sink for some contaminants, other studies have shown that some sediment contaminants can be remobilized under certain hydrologic conditions. Dredging also is associated with construction, repair, and maintenance of navigation structures (all M) as well as with bridge construction (M). Because these activities are anticipated to occur at specific locations relatively infrequently throughout the ORMSS time period, they are expected to have a lower cumulative impact on ecological services than activities like marina development and operation (M) that are increasing in number and are more widespread.

Residential, commercial, and industrial floodplain development (M) can impair effective nutrient cycling and purification services by replacing riparian vegetation with impervious surfaces that increase stormwater runoff, by compacting soils, and by altering hydrologic connectivity. Floodplain ordinances, government programs, and other constraints have limited floodplain development in recent years; however, some level of floodplain development is expected to occur throughout the study period. Renewed interest in recreational opportunities along the river, including the development of parks, trails/bikeways, private campgrounds, and other related facilities also can adversely impact ecological services, although the cumulative importance of these actions was typically ranked low in the RFFA matrix. From a positive perspective, recreational facilities may include enhancements that help restore native riparian vegetation and afford educational opportunities to demonstrate innovative BMPs.

Agriculture (M) represents the largest land use activity by area within or adjacent to the Ohio River floodplain. Erosion of cultivated land carries suspended solids and attached fertilizers, pesticides, and herbicides into the Ohio River mainstem, increasing pressure on nutrient cycling and purification processes. Additional demands result when livestock wastes run off into the river. Soil compaction from years of overuse and removal of riparian vegetation to maximize space for row crops further accelerate sediment and nutrient delivery to the river. The influence of agriculture on aquatic life, including fish, is underscored by the fact that most future conversions of land in the Ohio River corridor will occur on land currently in agriculture or in forests. Control of agricultural discharges (L), including BMPs promoted by the USDA Natural Resources Conservation Service, such as no-till farming, can help mitigate these impacts, but have limited effectiveness because these BMPs are largely voluntary.

Several actions listed in **Table 4-10** are beneficial to nutrient cycling and purification processes. Carbon sequestration ranks high (H) as a beneficial action, but is limited in practice. Future reforestation projects to capture and securely store carbon emitted from fossil fuel-fired energy plants may not only help reduce greenhouse gases, but may also help restore native riparian buffers along the Ohio River. More stringent quality standards

for environmental media (H), pollutant source control (H), ORSANCO's monitoring program (M), and spill response activities (M) collectively also can enhance ecological services in the Ohio mainstem.

4.10.5 Actions Contributing to Changes in Populations (P)

Included in this category are actions that inhibit or prevent normal reproduction and actions that cause isolation of fish communities. Actions with negative effects on population dynamics manifest themselves in the loss of species, populations, or genetic diversity. Information on the life history and population dynamics of species affected by human actions is important to understanding how populations and their ecological functions can change. The preservation of genetic diversity is critical to maintaining the evolutionary potential for fish to adapt to future stresses.

As mentioned in previous sections of this chapter, development of the navigation system and continuing operation maintenance of the locks and dams (H) have had profound influences on the distribution and composition of the fish community of the Ohio River. Siltation of the river bottom as a result of impoundment has contributed to declines in species such as shovelnose sturgeon, redhorses, blue sucker, paddlefish, and other species that use clean gravel substrate for spawning. Conversely, species such as freshwater drum, emerald shiner, and gizzard shad that produce floating eggs and larvae have increased in abundance. Impoundment (pool maintenance (H)) also has altered the hydrology in backwaters and side channels, consequently creating more lake-like embayments preferred by slower moving catfishes and sunfishes that are popular with anglers. Locks and dams also affect longitudinal distribution and may serve as barriers to the natural exchange of genetic material within a species. Lock extensions/rehabilitation (M) and dam replacement/rehabilitation (H) also may adversely affect local populations by damage to spawning habitat and nursery areas. The infrequency of these activities relative to operation and maintenance activities, however, produces relatively low cumulative impacts to fish communities.

Barge queuing (L), dispersed barge traffic (M), and increased barge traffic (H) are all actions that can cause damage or mortality of the most vulnerable life stages of certain fish species. The previously mentioned NAVPAT model has been developed as a tool to assess environmental effects on vulnerable life stages under various traffic scenarios.

Many other actions that are likely to increase with population growth include in-stream sand and gravel mining (H), operation of coal utilities (H), bridge construction (M), and marina development and operation (M). These actions affect fish populations through habitat alterations that are often long-term, depending on local populations and conditions. Operation of coal utilities (M) also can result in damage and mortality of fish due to impingement and entrainment, issues of concern in §316(b) of the CWA.

Non-structural navigation improvements (H) constitute non-regulatory actions perceived as having high importance and benefit to fish populations and their supporting habitats. Nonstructural navigation improvements refer to traffic management alternatives that do not involve modifications of lock and dam infrastructure. Because these nonstructural measures can facilitate passage of barge traffic, the impacts related to barge queuing, siltation, and physical damage to fish habitat and mussel beds are reduced. Nonstructural navigation improvements include efficiency measures such as vessel

scheduling and prioritization, self-help coordination among towboat operators, and expanded mooring facilities near locks and dams. More detailed information on nonstructural measures is found in Chapter 10, Transportation.

Of several actions **(Table 4-10)** to assess effects on fish, ORSANCO's monitoring (M) represents the most long-term effort to assess fish communities in the Ohio River and understand the factors that influence their sustainability. As part of USEPA's regional Environmental Monitoring and Assessment Program (EMAP), ORSANCO is beginning a five-year rotational monitoring program that includes sampling 30 randomly selected sites in each of four pools per year. The program is designed to assess regional comparability across similar ecosystems, as well as to complement ORSANCO's fish monitoring within the upper, middle, and lower river. ORSANCO also has been sampling Ohio River tributaries, in response to needs of its member states. Further, ORSANCO will continue to develop and evaluate indices of biotic integrity (IBIs), potentially including an index for algae. With regard to resource assessment, fishing (H) is important because fishermen can exert pressure to support monitoring, assessment, and regulatory programs that in turn enhance sustainability of the fisheries resources of the Ohio mainstem.

4.11 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

The fish fauna of the Ohio River represents a highly diverse and visible resource that has been studied more extensively than any other biotic group assessed for ORMSS. Because fish have multiyear life spans, are highly mobile, and occupy high positions in food webs, they are excellent indicators of CE and ES. Changes in current velocities and sediment transport related to the construction and operation of dams, along with poor water quality led to degradation of Ohio River fish communities through the mid-20th century. Actions undertaken by ORSANCO and the implementation of the CWA have helped reverse this trend since the 1970s. While Ohio River fish communities will not return to preimpoundment conditions due to habitat modifications, indices of biotic integrity have documented that the river's fish communities are now more diverse and healthy than in many decades. With point sources of water pollution under control and nonpoint sources being addressed, one of the greatest threats to fish communities in the Ohio River at the beginning of the 21st century appears to be the recent and rapid invasion of Asian carps species that aggressively compete with native fishes for food and ecological niches. However, to date, negative effects of Asian carps and most other invasive species have not been demonstrated.

One of the seven environmental operating principles of the Corps is to strive to achieve ES. ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation, and maintenance to improve the quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of cumulative effects can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An analysis of environmental sustainability (AES) has been and is being used in several other programmatic studies by the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps: (1) identification of five "common effects" on fish resources from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of six indicators for ES for fish and their grouping, as appropriate; and (3) consideration of the "connections" between the common effects and the indicator groups. The output of the AES consists of a qualitative (descriptive) discussion of the "connections," with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions – what is the current ES for fish resources, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable – the composite conditions for the six selected indicators of ES for fish do not reflect conditions that sustain diverse and healthy populations of fish in the Ohio River.

- Marginally sustainable – the composite conditions for the selected six indicators of ES for fish are such that diverse populations of fish are occurring in some segments of the river; however, the conditions of some of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of fish resources in the Ohio River).

- Sustainable – the composite conditions for the six selected indicators of ES for fish are such that diverse, healthy populations of fish are occurring along the majority of the river; as indicated by high values for indices of biotic integrity or other pertinent measures.

Five common effects of multiple actions have been previously discussed in the section entitled "Relevant Actions Affecting Fish." They include actions causing: 1) changes in habitat, 2) changes in disturbance regimes, 3) changes in hydrologic patterns, 4) effects on ecological services, and 5) changes related to fish populations. Six interrelated indicators of ES were identified earlier in the section entitled "Indicators of Environmental Sustainability," and relevant information on them has been presented in the section entitled "Past to Current Baseline Conditions." Regarding their relevance for ES, the following rationale is appropriate:

- composition of fish communities – including numbers of intolerant and nonnative species, abundance, and other metrics that have been incorporated into indices of biotic integrity; allows fish communities to be compared over time to determine trends affecting sustainability

- amount of habitat with stable substrates, adequate depths, suitable currents, and sufficient food supplies – related to reproductive success, condition of individuals in populations, and the overall diversity of fish communities

- reproductive viability as measured by amount of spawning habitat, genetic connectivity, numbers of gravid females, and larval individuals – directly related to the success of fish populations in attaining ES

- percent of population with abnormalities such as parasites, tumors, ulcers, and fin erosion – provides a measure of the health of individuals in populations and tends to increase with degradation in water quality

- water quality measurements such as levels of DO and pH – directly related to water quality standards established to protect aquatic life and human health and safety

- level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic – refers to an array of activities and conditions that can disrupt ecological processes and alter ES of fish communities and other aquatic organisms.

For the purposes of this analysis, the six indicators are grouped into two tiers for the AES. The tiers are as follows:

- first tier – basic measures related to fish resources

  (1) percent of population with abnormalities such as parasites, tumors, ulcers, and fin erosion

  (2) water quality measurements such as levels of DO and pH

  (3) level of disturbance from biotic stressors, such as invasive species, and from abiotic stressors, such as river traffic

- second tier – composite indicators of fish resources sustainability

  (1) amount of habitat with stable substrates, adequate depths, suitable currents, and sufficient food supplies

  (2) reproductive viability as measured by amount of spawning habitat, genetic connectivity, numbers of gravid females, and larval individuals

  (3) composition of fish communities, including numbers of intolerant and non-native species, abundance, and diversity

As noted in **Table 4-10**, the 61 RFFAs ranked as having high (H) or medium (M) importance to cumulative effects on fish can be grouped into categories in accordance with five common effects. **Table 4-11** summarizes the 38 RFFAs that cause adverse habitat changes (HA), including the integrity of critical habitats, patterns and connectivity of habitats, and structural complexity of habitats; and **Table 4-12** does similarly for the 22 RFFAs that cause beneficial habitat changes. In general, and as described above for selected examples of actions contributing to habitat changes, the 38 RFFAs in **Table 4-11** cause increases in the turbidity and suspended solids in water, decreases in DO, and changes in pH from normal conditions. Biotic stressors can occur and thus promote the occurrence of invasive species; and abiotic stressors can result from increased navigation and recreational boat traffic. Some actions may induce increasing percentages of abnormalities in existing fish populations. As a result of these undesirable changes in

basic measures related to fish populations, along with action-induced declines in adequate fish habitats and reproductive viability, the composite effect of these 38 RFFAs on the ES of fish resources in the Ohio River mainstem would lead to a reduced ES condition. Such reductions could exacerbate existing marginal ES conditions for many species, and create further concerns for currently nonsustainable species.

TABLE 4-11
AES Tiers for Actions Causing Adverse Habitat Changes (HA)

RFFAs That Cause Adverse Habitat Changes	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Lock extensions, new locks, replacement or rehabilitation (M) (2) Lock and dam operation and maintenance (M) (3) Dam replacement and rehabilitation (H) (4) Channel dredging/dredged material disposal (H) (5) Levees/floodwalls (H) (6) Dry dams, other projects off mainstem (M) (7) Channel modifications (M) (8) Emergency streambank stabilization (Sec. 14) (M) (9) Port development (Sec. 107) and maintenance dredging (M) (10) Pool maintenance (H) (11) Barge queuing (M) (12) Fleeting areas/barge storage (M) (13) Terminals (M) (14) Multi-modal sites (M) (15) Increased traffic (H) (16) Dispersed barge traffic (M) (17) Accidents/spills (H) (18) Instream sand and gravel mining (H) (19) Coal utilities (M) (20) Other coal industries (M) (21) Hydropower on dams (M) (22) Industrial users, excluding coal-related (M) (23) Floodplain development -- residential (M) (24) Floodplain development -- commercial (M) (25) Floodplain development -- industrial (M) (26) Crossings -- bridges (M) (27) Crossings -- utility (M) (28) Crossings -- industrial (M) (29) Riverbed crossings (M) (30) Marina development and operation (M) (31) Water-based recreation -- fishing (H)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

RFFAs That Cause Adverse Habitat Changes	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(32) Agriculture (M) (33) Wastewater treatment plant discharges -- municipal (H) (34) Wastewater treatment plant discharges -- industrial (H) (35) Wastewater treatment plant discharges -- onsite systems (H) (36) Stormwater discharges (H) (37) Hazardous waste sites (H) (38) Small navigation projects (M)		

TABLE 4-12
AES Tiers for Actions Causing Beneficial Habitat Changes (HA)

RFFAs That Cause Beneficial Habitat Changes	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Non-structural navigation improvements (H) (2) Non-structural measures (e.g., relocation) (H) (3) Modification of Corps structures for environmental improvements (Sec. 1135)(H) (4) Environmental restoration of aquatic ecosystems (Sec. 206)(H) (5) ERP projects - 5 categories (M) (6) Public lands acquisition and management (M) (7) Brownfields redevelopment (M) (8) Natural climatic effects - floods (H) (9) Natural climatic effects - droughts (H) (10) Natural climatic effects - severe storms (H) (11) Phase 1 and 2 NPDES program (H) (12) TMDLs (H) (13) Site remediation (H) (14) More stringent quality standards for environmental media (H) (15) Pollutant source control (H) (16) Wetland mitigation banking (H) (17) Farmland preservation (H) (18) Corps permitting programs (H) (19) ORSANCO monitoring program (M) (20) Spill response (M) (21) Endangered Species Act (H) (22) Environmental sustainability practices (H)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

Fortunately, and as illustrated by the 22 RFFAs in **Table 4-12**, several ER and improvement programs are already underway or planned. Further, natural climatic events are expected to contribute to periodic, albeit temporary, movement of the basic measures to more normal environmental cycling and variability. Twelve of the RFFAs listed in **Table 4-12** relate to the regulatory environment and policies and programs that should minimize disturbances from stressors, enhance water quality, and reduce fish population abnormalities. Therefore, as these RFFAs are implemented, they should improve the ES of fish resources in the Ohio River mainstem.

The RFFAs that are anticipated to cause changes in disturbance regimes are summarized in **Tables 4-13 and 4-14**. **Table 4-13** highlights the 15 RFFAs that are anticipated to cause adverse changes in conditions to which species and ecosystems have adapted over a long period of time. Disturbances are anticipated from both biotic and abiotic stressors. Water quality parameters may experience transient changes as a result of construction or rehabilitation practices associated with many of the RFFAs. Such transient conditions can promote abnormalities in fish populations and disruptions to substrates, depths, currents, and food supplies for fish habitats. These changes would be expected to reduce the reproductive viability of fish populations in local areas and to cause temporary and local reductions in the diversity and health of fish communities.

Table 4-14 lists 15 RFFAs that are anticipated to improve conditions to which species and ecosystems have adapted over long periods of time. The first 6 listed actions, along with numbers 10 through 15, are related to restoration or land acquisition actions, or to preservation, protection, and sustainability actions that should reduce biotic and abiotic stressors and improve water quality, fish habitat, and fish reproductive viability. Actions 7 through 9 are associated with natural climatic effects that should mimic longer-term environmental conditions and regimes. As a composite result of these 15 RFFAs, the ES of fish resources would be expected to improve.

Tables 4-15 and 4-16, respectively, summarize 24 and 16 RFFAs that either adversely or beneficially affect hydrologic patterns. A key feature is that changes in these patterns include alterations to water connections that influence biodiversity and ecological integrity. Such connections can occur on tributaries, in the upstream to downstream flow patterns on the mainstem, and in runoff waters from adjacent urban and rural areas. Adverse changes to natural hydrologic connections can cause both changes in flow patterns and velocities as well as water quality. Disturbances to the quality and quantity of fish habitats, as well as fish behavioral patterns can result. The reproductive viability of various species can also be disrupted. As a consequence of the adverse changes to hydrologic patterns, the diverse and healthy composition of existing fish communities will be lowered, and the ES of fish resources will be reduced.

TABLE 4-13
AES Tiers for Actions Causing Adverse Changes in Disturbance Regimes

RFFAs That Cause Adverse Changes in Disturbance Regimes	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Lock extensions, new locks, replacement or rehabilitation (M) (2) Lock and dam operation and maintenance (M) (3) Dam replacement and rehabilitation (H) (4) Levees/floodwalls (H) (5) Dry dams, other projects off mainstem (M) (6) Channel modifications (M) (7) Port development (Sec. 107) and maintenance dredging (M) (8) Pool maintenance (H) (9) Terminals (M) (10) Multi-modal sites (M) (11) Floodplain development -- residential (M) (12) Floodplain development -- commercial (M) (13) Floodplain development -- industrial (M) (14) Hazardous waste sites (H) (15) Small navigation projects (M)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

TABLE 4-14
AES Tiers for Actions Causing Beneficial Changes in Disturbance Regimes

RFFAs That Cause Beneficial Changes in Disturbance Regimes	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Non-structural measures (e.g., relocation) (H) (2) Modification of Corps structures for environmental improvements (Sec. 1135)(H) (3) Environmental restoration of aquatic ecosystems (Sec. 206)(H) (4) ERP projects - 5 categories (M) (5) Public lands acquisition and management (M) (6) Brownfields redevelopment (M) (7) Natural climatic effects - floods (H) (8) Natural climatic effects - droughts (H) (9) Natural climatic effects - severe storms (H) (10) Site remediation (H) (11) Wetland mitigation banking (H) (12) Farmland preservation (H) (13) COE permitting programs (H) (14) Endangered Species Act (H) (15) Environmental sustainability practices (H)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

TABLE 4-15
AES Tiers for Actions Causing Adverse Changes to Hydrologic Patterns (Hy)

RFFAs That Cause Adverse Changes to Hydrologic Patterns (Hy)	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Lock extensions, new locks, replacement or rehabilitation (M) (2) Lock and dam operation and maintenance (M) (3) Dam replacement and rehabilitation (H) (4) Channel dredging/dredged material disposal (H) (5) Levees/floodwalls (H) (6) Dry dams, other projects off mainstem (M) (7) Channel modifications (M) (8) Emergency streambank stabilization (Sec. 14) (M) (9) Port development (Sec. 107) and maintenance dredging (M) (10) Pool maintenance (H) (11) Terminals (M) (12) Multi-modal sites (M) (13) Instream sand and gravel mining (H) (14) Coal utilities (M) (15) Other coal industries (M) (16) Industrial users, excluding coal-related (M) (17) Floodplain development -- residential (M) (18) Floodplain development -- commercial (M) (19) Floodplain development -- industrial (M) (20) Crossings -- bridges (M) (21) Marina development and operation (M) (22) Agriculture (M) (23) Hazardous waste sites (H) (24) Small navigation projects (M)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

Table 4-16 lists the16 RFFAs that could cause beneficial effects on hydrologic patterns, depending on specific locational and design features of the actions. Actions (1) through (4), (6), (11) and (12) are examples of restoration, remediation, or reclamation measures that could be designed with one purpose being to restore natural connectivity. Land acquisition and management measures, including management of hydrologic patterns, are included in actions (5) and (13), and possibly (16). The natural climatic events depicted in actions (7) through (9) are related to natural means for restoring altered connectivities. Finally, regulatory requirements for protecting hydrologic patterns can be imposed under actions (10), (14), and (15), along with action (16). In summary, the 16 RFFAs in **Table 4-16** would enhance the ES of fish resources in the Ohio River mainstem.

TABLE 4-16
AES Tiers for Actions Causing Beneficial Changes to Hydrologic Patterns

RFFAs That Cause Beneficial Changes to Hydrologic Patterns	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Non-structural measures (e.g., relocation) (H) (2) Modification of Corps structures for environmental improvements (Sec. 1135)(H) (3) Environmental restoration of aquatic ecosystems (Sec. 206)(H) (4) ERP projects - 5 categories (M) (5) Public lands acquisition and management (M) (6) Brownfields redevelopment (M) (7) Natural climatic effects - floods (H) (8) Natural climatic effects - droughts (H) (9) Natural climatic effects - severe storms (H) (10) Phase 1 and 2 NPDES program (H) (11) Site remediation (H) (12) Wetland mitigation banking (H) (13) Farmland preservation (H) (14) COE permitting programs (H) (15) Endangered Species Act (H) (16) Environmental sustainability practices (H)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

Table 4-17 displays 20 RFFAs that are expected to cause adverse effects on ecological services; examples of effects include those on nutrient cycling and purification services that break down toxins and transform soils and sediments. Many of the listed actions would cause adverse effects during their construction phases, and others would contribute to such effects during their operational phases. The effects would be manifested on both "basic measures" and "composite indicators." Accordingly, a decline in the ES of fish resources would be expected to occur, with the decline ultimately reflected in fewer diverse and healthy fish communities.

TABLE 4-17
AES Tiers for Actions Causing Adverse Effects on Ecological Services (EcS)

RFFAs That Cause Adverse Effects on Ecological Services	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Lock and dam operation and maintenance (M) (2) Dam replacement and rehabilitation (H) (3) Channel dredging/dredged material disposal (H) (4) Levees/floodwalls (H) (5) Dry dams, other projects off mainstem (M) (6) Channel modifications (M) (7) Port development (Sec. 107) and maintenance dredging (M) (8) Pool maintenance (H) (9) Terminals (M) (10) Multi-modal sites (M) (11) Coal utilities (M) (12) Other coal industries (M) (13) Floodplain development -- residential (M) (14) Floodplain development -- commercial (M) (15) Floodplain development -- industrial (M) (16) Crossings -- bridges (M) (17) Marina development and operation (M) (18) Agriculture (M) (19) Hazardous waste sites (H) (20) Small navigation projects (M)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

In contrast to adverse effects on ES, **Table 4-18** displays 21 RFFAs that are anticipated to cause beneficial effects on such services. The 21 RFFAs include those related to environmental improvements via the use of non-structural measures (no. 1), modifications and restoration efforts (nos. 2 through 4), land acquisition and management (nos. 5, 14, 15, and 16), natural climatic effects (nos. 7, 8, and 9), environmental controls, monitoring, and regulatory programs (nos. 10, 12, 13, 17, 18, 19, and 20), remediation efforts (nos. 5 and 11), and promotion and implementation of ES practices (no. 21). Some of these RFFAs reflect continuations of current measures, while others would be implemented at various times over the planning period. Overall beneficial effects are expected to occur from reduced pollutants released to the environment and less disruptions to natural biotic and abiotic processes.

TABLE 4-18
AES Tiers for Actions Causing Beneficial Effects on Ecological Services

RFFAs That Cause Beneficial Effects on Ecological Services	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Non-structural measures (e.g., relocation) (H) (2) Modification of Corps structures for environmental improvements (Sec. 1135)(H)	• Percent of Fish Populations with Abnormalities	• Amount of Adequate Habitat • Reproductive

RFFAs That Cause Beneficial Effects on Ecological Services	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(3) Environmental restoration of aquatic ecosystems (Sec. 206)(H) (4) ERP projects - 5 categories (M) (5) Public lands acquisition and management (M) (6) Brownfields redevelopment (M) (7) Natural climatic effects - floods (H) (8) Natural climatic effects - droughts (H) (9) Natural climatic effects - severe storms (H) (10) Phase 1 and 2 NPDES program (H) (11) Site remediation (H) (12) More stringent quality standards for environmental media (H) (13) Pollutant source control (H) (14) Wetland mitigation banking (H) (15) Carbon sequestration (H) (16) Farmland preservation (H) (17) COE permitting programs (H) (18) ORSANCO monitoring program (M) (19) Spill response (M) (20) Endangered Species Act (H) (21) Environmental sustainability practices (H)	• Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	Viability • Diverse and Healthy Composition of Fish Communities

Tables 4-19 and 4-20, respectively, address adverse and beneficial changes to fish populations resulting from RFFAs. Such changes include the impacts of exotic species, alterations in population dynamics, and modifications of genetic diversity. A total of 31 RFFAs that could have adverse effects are listed in **Table 4-19**, while 22 RFFAs that could cause beneficial effects are listed in **Table 4-20**. Examples of actions causing both types of effects are described in the earlier subsection entitled "Actions Contributing to Changes in Populations." The RFFAs listed in **Table 4-19** would be expected to decrease the ES of fish resources, while those in Table 20 would enhance the ES.

TABLE 4-19
AES Tiers for Actions Causing Adverse Changes to Fish Populations

RFFAs That Cause Adverse Changes to Fish Populations	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Lock and dam operation and maintenance (M) (2) Dam replacement and rehabilitation (H) (3) Levees/floodwalls (H) (4) Dry dams, other projects off mainstem (M) (5) Channel modifications (M) (6) Port development (Sec. 107) and maintenance dredging (M) (7) Pool maintenance (H) (8) Barge queuing (M) (9) Terminals (M) (10) Multi-modal sites (M)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

RFFAs That Cause Adverse Changes to Fish Populations	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(11) Increased traffic (H) (12) Dispersed barge traffic (M) (13) Accidents/spills (H) (14) Instream sand and gravel mining (H) (15) Coal utilities (M) (16) Other coal industries (M) (17) Hydropower on dams (M) (18) Industrial users, excluding coal-related (M) (19) Floodplain development -- residential (M) (20) Floodplain development -- commercial (M) (21) Floodplain development -- industrial (M) (22) Crossings -- bridges (M) (23) Marina development and operation (M) (24) Water-based recreation -- fishing (H) (25) Agriculture (M) (26) Wastewater treatment plant discharges -- municipal (H) (27) Wastewater treatment plant discharges -- industrial (H) (28) Wastewater treatment plant discharges -- onsite systems (H) (29) Stormwater discharges (H) (30) Hazardous waste sites (H) (31) Small navigation projects (M)		

TABLE 4-20
AES Tiers for Actions Causing Beneficial Changes to Fish Populations

RFFAs That Cause Beneficial Changes to Fish Populations	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(1) Non-structural measures (e.g., relocation) (H) (2) Modification of Corps structures for environmental improvements (Sec. 1135)(H) (3) Environmental restoration of aquatic ecosystems (Sec. 206)(H) (4) ERP projects - 5 categories (M) (5) Public lands acquisition and management (M) (6) Brownfields redevelopment (M) (7) Natural climatic effects - floods (H) (8) Natural climatic effects - droughts (H) (9) Natural climatic effects - severe storms (H) (10) Phase 1 and 2 NPDES program (H) (11) TMDLs (H) (12) Site remediation (H) (13) More stringent quality standards for environmental media (H) (14) Pollutant source control (H) (15) Wetland mitigation banking (H) (16) Carbon sequestration (H) (17) Farmland preservation (H)	• Percent of Fish Populations with Abnormalities • Water Quality Measurements • Level of Disturbance from Biotic and Abiotic Stressors	• Amount of Adequate Habitat • Reproductive Viability • Diverse and Healthy Composition of Fish Communities

RFFAs That Cause Beneficial Changes to Fish Populations	Basic Measures Related to Fish Resources	Composite Indicators of Fish Resources Sustainability
(18) COE permitting programs (H) (19) ORSANCO monitoring program (M) (20) Spill response (M) (21) Endangered Species Act (H) (22) Environmental sustainability practices (H)		

To summarize the overall AES, **Table 4-21** includes tabulations associated with the numbers and importance of RFFAs contributing to adverse and beneficial changes to the five categories of fish effects. Some general observations related to **Table 4-21** include:

- Adverse changes to the five categories of effects generally lead to declines in the ES of fish resources, while beneficial changes cause improvements in ES.

- RFFAs associated with adverse changes include a composite of construction and operational practices that will occur at various locations along the mainstem and at various times across the planning horizon. The majority of the RFFAs are associated with navigation investment actions by the Corps, other Corps actions, "but for" actions by others but related to presence of the navigation system, and general actions by others. The majority of the listed RFFAs anticipated to cause adverse changes are in the medium importance category.

- RFFAs associated with beneficial changes include a composite of restoration, protection, and remediation projects, along with natural climatic events, and permitting and environmental management programs associated with the regulatory environment. Some of these RFFAs represent continuations of past and present actions; however, the majority are dependent on future funding and new regulatory or management initiatives. Again, the beneficial changes from these actions are expected to occur at various locations along the mainstem and at various times across the planning horizon. Finally, the large majority of the listed RFFAs anticipated to cause beneficial changes are in the high importance category.

- The composite pattern indicated by **Tables 4-11 through 4-20**, as well as summarized in **Table 4-21**, is that in the short-term future (perhaps the next decade), the ES of fish resources would decline; however, in the longer-term future the beneficial changes would more than offset the adverse changes, thus the ES of fish resources would improve relative to the current conditions.

TABLE 4-21
Summary of Analysis of Environmental Sustainability

Effects on Fishes	RFFAs Causing Adverse Changes	RFFAs Causing Beneficial Changes
Habitat changes (HA)	Table 11 -- 38 RFFAs (14 H and 24M)	Table 12 -- 22 RFFAs (17 H and 5 M)
Changes in disturbance regimes (DR)	Table 13 -- 15 RFFAs (4H and 11M)	Table 14 -- 15 RFFAs (12H and 3M)

Effects on Fishes	RFFAs Causing Adverse Changes	RFFAs Causing Beneficial Changes
Changes in hydrologic patterns (Hy)	Table 14 -- 15 RFFAs (12H and 3M)	Table 16 -- 16 RFFAs (13H and 3M)
Effects on ecological services (EcS)	Table 17 -- 20 RFFAs (5H and 15M)	Table 18 -- 21 RFFAs (16H and 5M)
Changes related to fish populations (P)	Table 19 -- 31 RFFAs (14H and 17M)	Table 20 -- 22 RFFAs (17H and 5M)
Note: H denotes a high importance RFFA, and M denotes a medium importance RFFA		

4.12 SUMMARY AND CONCLUSIONS

The CE on Ohio River fishes from past, present, and reasonably foreseeable future actions have been addressed herein. Because of their importance to humans and their diversity, fish are a VEC in ORMSS. These resources further are valued because they serve as indicators of the quality and overall health of the aquatic ecosystem. Their indicator role is facilitated by their multiyear life spans and mobility, their wide range of species, trophic levels, and spawning conditions; their sensitivity to pollution, and their collection methods and relative ease of identification. Fish also are of interest and concern to society because of their potential for food and sport.

Fishes of the Ohio River interact with several other VECs including water and sediment quality, mussels, riparian/floodplain ecological resources, recreation, land use, and human health. Fish species composition, abundance and condition are all related to water and sediment quality. Fish and mussels generally have mutually beneficial interactions; mussels are an important food resource for certain bottom-dwelling fishes, including suckers and catfish. Conversely, fish are critical to mussel distribution because they serve as hosts for the immobile, glochidial (larval) stage of mussels. Riparian habitats, including wetlands and embayments, provide vital spawning areas for many fish species and their somewhat lower current velocities and higher temperatures offer refuges to fish during winter. Riparian habitats are important to processes for improving water quality and nutrient cycling providing benefits to fish, mussels, and other natural resources. Water quality improvements in recent decades have enhanced sports fishing which in turn has enhanced the perception of the river's recreational value. Despite improved water quality, fish consumption advisories remain in effect for a number of Ohio River species. Pollutants that affect fish are generated by an array of human activities, exacerbated by increased imperviousness and runoff from land.

The geographic boundaries for study of the fish VEC included the mainstem, the approximate 500-year floodplain zone along both sides of the river, and mouths of tributaries. More information is needed on the contribution of tributaries to the recruitment and sustaining of fish in the Ohio mainstem. The temporal boundaries of this study generally encompass 1920 to 2070, with the earlier date approximating the initiation of the Corps' lock and dam construction activities on the Ohio River and the latter date approximating the end of the 60-year planning horizon encompassed by ORMSS. However, some information prior or 1920 is included to establish an historic baseline.

Fish populations were identified in early study planning by the Corps and the IWG as an important topical issue to be addressed. This identification was confirmed via the number of comments and specific concerns expressed in 12 public scoping meetings. A total of 26 direct comments on fish were received, along with an additional 49 comments that have implications for fish and fishing. These comments have been addressed herein. Further, the Environmental Review Team has continued to express interest in, and provide information and advice on this VEC.

Several federal laws are related either directly or indirectly to fish in the mainstem. Biologically-focused laws include the Endangered Species Act, the Fish and Wildlife Coordination Act, National Invasive Species Act, and state fishing regulations. The ORFMT, composed of fisheries personnel for the six states bordering the river, has worked to facilitate fishing license reciprocity and standardize fishing regulations along the river. The CWA relates to water quality improvements; it also encompasses programs involving state water quality certification (Section 401), the Corps' Section 404 permitting of dredged and fill material, the NPDES program (Section 402) for point and nonpoint pollution sources, and the regulation of cooling water withdrawals and discharges (Sections 316 a & b). Monitoring of water quality, fish communities, and other related aquatic ecological components is routinely conducted by ORSANCO. Regulations applicable to wetlands and publicly-owned properties (e.g., federal and state wildlife refuges) also benefit fish habitat.

4.12.1 Describing the Affected Environment

Six indicators describing the essentials for diverse and ES fish communities in the mainstem were utilized in this CEA. They included: 1) composition of fish communities, including numbers of intolerant and nonnative species, abundance, and diversity; 2) amount of habitat with stable substrates, adequate depths, suitable currents, and sufficient food supplies; 3) reproductive viability as measured by amount of spawning habitat, genetic connectivity, numbers of gravid females, and larval individuals; 4) percent of the population with abnormalities such as parasites, tumors, ulcers, and fin erosion; 5) water quality measurements such as levels of DO, and pH; and 6) level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic. The entire suite of indicators may be essential to adequately characterize and track Ohio River fish communities. In contrast to several other VECs, long-term data are available for several indicators of fish sustainability.

A total of 159 species of fish have been reported for the Ohio River main stem since the early 19th century. Reports prior to 1920 list 111 species; those from 1920-1969 list 121; and those from 1970-1988 list 140 species. Many human activities affected the river's environment before 1920, including clearing of forests and draining of wetlands leading to siltation, turbidity, and habitat loss. After about 1900, species tolerant of siltation and turbidity increased in numbers, including black bullhead, goldeye, skipjack herring, gizzard shad, and spotted bass. Before completion of the wicket dams in the early 20th century, large river species such as shovelnose sturgeon, paddlefish, muskellunge, and blue sucker had declined due to a variety of factors such as untreated municipal and industrial wastes, mine drainage, and unregulated modifications of aquatic and riparian zones. Rapid growth of human populations in the Ohio basin during the first half of the 20th century, led to larger inputs of domestic sewage, industrial effluents, and acid mine drainage. Historic

large river species continued to decline, and gizzard shad, emerald shiner, freshwater drum, and the introduced common carp became dominant. The fish fauna of the more populous, industrialized upper river became depauperate. Actions by ORSANCO and implementation of the CWA helped reverse these trends such that an upward trend in fish diversity in the upper Ohio has been documented in the last 20 years. Many species that disappeared from the upper river during the worst decades of pollution have returned to portions of the river approximating their historical ranges. Between 1984 and 1989, range extensions of mainstem fishes included 12 species in an upstream direction, 14 species in a downstream direction and six species both upstream and downstream. The availability, connectivity among, and access to complex habitat types that provide for spawning, nursery, feeding, and over-winter refugia is very dynamic.

The present system of high lift dams has altered aquatic habitats by converting the Ohio River from a free-flowing waterway to one of relatively constant width and a minimum maintained channel depth of 9 feet. The modern navigation system, combined with land use and flood control practices in the watershed, has resulted in the inundation and siltation of extensive areas of gravel substrate preferred by important fish species, particularly in the lower half of the river. High lift dams have also reduced connectivity of habitats and movements of riverine fishes. Concurrent with reductions in migratory species related to high-lift dams has been the creation of nearly 80 embayments in creek mouths adjacent to the mainstem in the upper half of the river. Such slow-moving waters offer important habitat for black basses and other sunfishes, species more typical of lake-like conditions. The importance of embayments has been documented, but many embayments in the lower river are not accessible to fishes when such habitat is most critical.

Eight historic Ohio River fish species not found since 1920 are the least brook lamprey, Alabama shad, hornyhead chub, Ozark minnow, and the mud, longhead, crystal, and gilt darters. Regarding Ohio River fishes listed under the federal Endangered Species Act, five species have been identified as species of special concern (SSC): the paddlefish (*Polyodon spathula*), blue sucker (*Cycleptus elongatus*), crystal darter (*Ammocrypta asprella*), Eastern sand darter (*Ammocrypta pellucida*), and longhead darter *(Percina macrocephala*).

ORSANCO and other agencies have collaborated to develop an IBI specifically tailored to the distinctive ecological characteristics of the Ohio River. The resulting index, the ORFIn incorporates 13 attributes of Ohio River fish communities (see **Table 4-6** for additional details). ORFIn is sensitive to a wide range of habitat and water quality conditions and is being used to develop biological criteria for possible incorporation into ORSANCO's Pollution Control Standards. ORFIn scores, which range from 1 - 65 have been found to be lower at shallow sites with sand and fine substrates and higher at deeper sites with coarse substrates, clear water, and cooler temperatures, conditions favorable to gravel-spawning fish species typical of the preimpoundment Ohio River. Evaluation and refinement of ORFIn as a sustainability assessment tool will continue over the next several years.

Because of the conspicuousness, ecological, economic, and recreational importance of fish, many studies have been conducted to determine the effects of various human actions on fishes of the Ohio River. As discussed throughout this chapter, several studies

have considered the specific effects of navigation infrastructure (see Environmental Appendix, Volume 2), commercial transportation, and power generation (various published and unpublished literature sources). Some studies were specifically designed and conducted to address data gaps identified in the ORMSS scoping process. Key observations from these studies follow:

- A study on upstream fish passage at Ohio River dams was undertaken to examine the importance of longitudinal connectivity in sustaining the bioproduction and biodiversity of migratory fishes. The study related historical hydraulic conditions at the dams to swimming capabilities of 44 selected species to determine if dams are restricting upstream movements of fish. Targeted species were selected in consultation with the ORMSS IWG and through review of pertinent literature. The study findings suggest that upstream fish passage opportunities generally occur during open-river rather than controlled conditions at dams. An analysis of historical water elevation data at Ohio River mainstem dams revealed that the frequency of open river by calendar week (hence, the potential for fish passage) varied spatially along the river by dam and temporally with discharge. The general spatial pattern of open river indicated the potential for fish passage decreases from downstream to upstream as open river conditions are less likely and less frequent in the upper river compared to the lower river. Consequently, the potential for passage is low to high at dams in the Louisville District (Dam 53 through McAlpine – seven dams), low to moderate at Huntington District dams (Meldahl through Willow Island – six dams), and low at Pittsburgh District dams (Hannibal through Emsworth – six dams). In general, open-river conditions were more frequent during winter and spring and generally were nonexistent during summer and fall, coinciding with the low-flow period. The study suggests that because large river fish populations evolved under conditions less restrictive to longitudinal movement than presently exist, conditions created by mainstem dams probably affect the distribution, abundance, and productivity of migratory species by imposing limitations on life cycle completion and interactions among localized fish populations. The study recommends moving beyond species and site specific management towards more systemic considerations that could include both operational and structural measures to improve fish passage at mainstem dams on the river.

- Four additional studies undertaken for ORMSS related to fish movement and passage in the Ohio River and were conducted by the WVDNR in coordination with the ORFMT. These studies, which corroborate some findings of the upstream fish passage study, are briefly summarized below:

    1) The Fish Passage Direct Observations Study, conducted at Winfield L/D on the Kanawha River, showed that large river migratory fishes (e.g., white bass, skipjack herring, and sauger) were more common in tailwater areas than in the lock chambers, while species typical of more lentic (lakelike) conditions (e.g., channel catfish) were more common in the lock chambers. The findings support ORSANCO data indicating that fewer large river species are collected in traditional lock chamber surveys than expected based on their overall abundance in the river. Further, although flow attraction operations within lock chambers are part of lock chamber

sampling protocol, results of the direct observation study led to the reasoning that many migratory species are not attracted to flow conditions in lock chambers and, therefore, miss opportunities to pass through lock/dam complexes during typical navigational lockage operations.

2) The Fish Tagging and Recovery Study, conducted in nine tailwater areas along the Ohio River, supported the findings of the Fish Passage Direct Observations Study and indicated that migratory fishes' affinity for flowing waters inhibits them from gravitating to lock chambers. Instead, their interpool movement appears to be facilitated by more open river conditions, which occur more frequently at some L/Ds than at others.

3) The Recreational Fish Survey, conducted on more than 8,500 angler trips at eight tailwaters for at least a 12-month period covering all seasons, found that the number of anglers fishing for "any species" exceeded the number targeting a single species or group and totaled 33 percent of anglers on the river overall. Geographic differences also were observed in species sought; for example, percids were sought in more upstream tailwaters while catfish were sought more frequently in downstream tailwaters. Consumption advisories may explain that fewer fish were harvested (kept) by anglers in the more industrialized upper river than in the more rural lower river.

4) A Glochidial Infestation Study resulted in the collection of 31 fish species representing a wide range of behavioral and habitat guilds primarily from Ohio River tailwaters because of the potential presence of mussels in these more free-flowing sections of the river as well as the congregation of fish there. Of 536 fish examined for infestation with the mussel glochdial life stage, only four individuals were infested. Due to the low numbers of glochidia found, no conclusions could be made regarding fish hosts and interpool passage. A literature review for the study cited similar low infestation rates for fish from the Green River in Kentucky, a major tributary to the Ohio River.

- Studies on the effects of towboat operation on large rivers indicate that propellers of commercial towboats can cause abrupt changes in hydraulic patterns, including increased turbulence and water velocities with resulting injury or mortality of adult fish, eggs, and larval stages. Field investigations of these effects have been limited, in part because of the difficulty of sampling organisms in turbulent water behind large vessels. Two recent studies prepared for the Corps on the Upper Mississippi River-Illinois Waterway may be applicable to the Ohio mainstem. First, a study of larval shovelnose sturgeon, larval lake sturgeon, eggs and larvae of paddlefish, juvenile common carp, and larval blue sucker (all species recorded for the Ohio mainstem.) found that larval mortalities varied by size and species, with higher tolerances by larger individuals and by species adapted to higher velocity habitats. The study concluded that shear stress created by propellers can be a major source of larval fish mortality. Linear relationships between mortality and shear stress suggest that mortality can be predicted for different towboat configurations and extrapolated to approximate impacts of increased navigation traffic. The second study, conducted in Pool 26 of the Upper Mississippi and Alton Pool in the Illinois

River, concluded that with high annual tow traffic, even small entrainment mortality rates can yield high estimates of annual losses. Anecdotal evidence from Pool 26 also suggested that some fish are killed during acceleration of downbound tows as they exit locks.

- While ORMSS did not undertake a study on the effects of recreational boating on fish and habitat, a literature review by the North American Lake Management Society emphasizes that impacts of recreational boating on fish and other aquatic life are most pronounced in shallow waters and are compounded by the coinciding of peak boating activity with critical life stages of aquatic organisms during warmer months. Wave action by high-speed watercraft can disturb or destroy spawning nests, promote shoreline erosion, smother fish eggs and habitat, and lead to gill damage causing decreased growth rates and lower fish biomass overall. Most studies cited in the literature review focus on lakes and reservoirs and fish species that typically inhabit them. Because scant information exists on the effects of recreational boating on large rivers, it remains a topic ripe for additional research.

- A study of winter habitat used by fishes in the Ohio River, conducted during two winters in the Belleville and Smithland Pools, found that during both winters and in both pools, fish assemblages and abundances differed among the winter macrohabitats: In Smithland Pool, habitats adjacent to the main channel appeared to be important for fish during the winter, including island backwaters, submerged boulders at the channel border, and deep scours created by artificial structures. Tributary macrohabitats in Smithland Pool only appeared to provide important winter habitat when temperatures were low and when these areas were connected to the main channel. In Belleville Pool, tributaries and an embayment area appeared to play a critical role for wintering fishes, although such macrohabitats may cool more than the main channel during snow melt, necessitating movement of fish into warmer main channel areas. The unique opportunity to conduct parallel research projects in two Ohio River pools during the same winters provided several insights into the potential effects of increased navigation on fish assemblages: 1) Tributary habitats are clearly important to wintering fish; reduced connectivity of tributaries in Smithland Pool likely compromises the success of many species. 2) Artificial sites such as wing dikes in Smithland Pool create scours used by river fishes, although some concern about displacement by barges persists, requiring further exploration. 3) Island backwater areas appear particularly important for fishes during winter. In the Ohio mainstem, quantity and availability of winter refuge may well determine the relative survival and abundance of resident fish populations. Therefore, river habitat management that maintains or enhances accessibility to these areas should be beneficial to wintering fish in the Ohio River.

- Studies on the effects of cooling water intake structures on fish have been undertaken along the Ohio River since the 1970s in conformance with Section 316(b) of the Clean Water Act. In accordance with new and proposed regulations related to §316(b), USEPA recently evaluated entrainment and impingement rates at nine power plants on the Ohio mainstem between RM 53.9 and 560. The main fish species the study found to be at risk were emerald shiner, freshwater drum, gizzard shad, sauger, white bass, white crappie, and white sucker. Several of these species have floating (pelagic) eggs or larvae that make them more vulnerable to damage

from water intakes. Further §316(b) studies at several power plants along the Ohio River are anticipated as additional phases of the revised 316(b) program are implemented by USEPA in the coming years.

Finally, relative to describing the affected environment, the Navigation Predictive Analysis Technique (NAVPAT) model is a tool developed by the Corps – Louisville District to evaluate river traffic-induced impacts on habitat for fish and other aquatic life (see Environmental Appendix, Volume 2, NAVPAT Report). In general, NAVPAT links tow movements to possible biological effects. The NAVPAT model considers 15 life-stages of fishes selected to represent guilds of all major habitats and life stages in a river system. Although refinements to NAVPAT continue, the model has been used to evaluate environmental effects near Olmstead L/D and McAlpine L/D.

4.12.2 Assessing the Cumulative Effects of Past, Present, and Future Actions

Multiple past and present actions have affected the fish of the mainstem, and multiple future actions also are anticipated to contribute to the overall CE on the fish VEC. The systematic evaluation of 87 types of RFFAs indicated that 32 were ranked as having "high importance" for fish relative to CE, and 28 were designated as having "medium importance." One RFFA was ranked as both high and medium. The importance rankings for the actions reflect the composite consideration of the future time period of occurrence, likelihood of occurrence, potential for multiple locations along the river, the spatial and temporal extent of the anticipated effects, the level of knowledge about the effects, the relative contribution to the CE, and the possibilities for cost-effectively mitigating the negative consequences. The fact that 60 of the 87 RFFAs were ranked as having high or medium importance reflects several values, including the biological, economic, and recreational importance of fish.

The 60 ranked RFFAs have been divided into five categories based on their "common primary effects;" that is, actions contributing to habitat changes, actions causing changes in disturbance regimes, actions causing changes in hydrological patterns, actions affecting ecological services, and actions related to population changes. (It should be noted that some actions could have been listed for more than one category; however, the assignment was based on their "primary effects.") The first category includes actions that physically alter fish habitat, including changing its structural complexity, overall patterns, and connectivity. Many actions are listed in this category, including channel maintenance dredging, in-stream sand and gravel mining, construction of lock chamber extensions, barge queuing or barge fleeting and storage, periodic upkeep and maintenance of lock and dam facilities, major lock or dam rehabilitation projects, port development and maintenance, development of new terminals and multimodal sites, recreational boat marinas and launch ramps, industrial discharges, coal utilities and other coal-related industries, all types of floodplain development, the Phase 1 and 2 NPDES program, riverbed crossings, and Corps permitting programs. Examples of how these actions affect habitats were described earlier.

Actions that cause changes in disturbance regimes include altering conditions to which fish species and ecosystems have adapted over a long period of time. Examples of such actions include floods, droughts, severe storms and earthquakes; dry dams and other

off-mainstem flood control projects; and channel modifications designed to reduce flooding. Descriptions of how these actions indirectly affect habitat and instability were described earlier.

Actions that cause changes to hydrologic patterns are closely linked to changes in disturbance regimes and habitat and include alterations to water connections that influence biodiversity and ecological integrity. Examples of such actions include bridge construction, levees, ER projects, brownfields redevelopment, remediation of contaminated sites, and the Phase 1 and 2 NPDES programs. Again, descriptions of how these actions change hydrologic patterns were described earlier.

Actions affecting ecological services have impacts on nutrient cycling and purification services that break down toxins and transform soils and sediments. Although most of these actions occur in the floodplain, an exception is channel dredging, considered an action of high importance. Other examples of actions affecting ecological services are construction, repair, and maintenance of navigation structures; bridge construction, marina development and operation; all types of floodplain development, agriculture, and control of agricultural discharges; carbon sequestration, more stringent environmental standards; pollutant source control; ORSANCO's monitoring program; and spill response activities.

The last category, actions contributing to population changes, includes actions that inhibit or prevent normal reproduction or cause isolation of fish communities. Such actions with negative effects manifest themselves in the loss of species, populations, or genetic diversity. Examples in this category include operation and maintenance of locks and dams, lock extensions/rehabilitation, dam replacement/rehabilitation, barge queuing, dispersed barge traffic, increased barge traffic, in-stream sand and gravel dredging, operation of coal utilities, bridge construction, marina development and operation, nonstructural navigation improvements, and ORSANCO's monitoring program.

ES has been used as the "ultimate test" whereby the significance of CE from multiple past, present, and future actions on fish can be qualitatively evaluated. The analysis of ES (AES) involved "connecting" the five common effects from the 60 high and medium importance RFFAs to the six indicators of ES used to describe the historical situation, trends, and current conditions of the fish VEC. For purposes of this analysis, the indicators were divided into two tiers and re-grouped. The first tier included "basic measures related to fish resources" and encompassed the percent of population with abnormalities such as parasites, tumors, ulcers, and fin erosion; water quality measures such as levels of DO and pH; and level of disturbance from biotic stressors, such as invasive species and from abiotic stressors, such as river traffic. The second tier, called "composite indicators of fish resources sustainability," encompasses the three additional indicators: amount of habitat with stable substrates, adequate depths, suitable currents, and suitable food supplies; reproductive viability as measured by amount of spawning habitat, genetic connectivity, numbers of gravid females and larval individuals; and composition of fish communities, including numbers of intolerant and non-native species, abundance, and diversity. The qualitative discussion of the connections was based on available quantitative data, fundamental scientific information, and professional judgment.

After the connections were discussed, the conditions for the composite indicators were evaluated based on three categories of ES defined as follows:

- Not sustainable – the composite conditions for the selected indicators of ES for fish do not reflect conditions that would sustain diverse, healthy populations of fish in the Ohio River.

- Marginally sustainable – the composite conditions for the selected indicators of ES for fish are such that diverse populations of fish are occurring along some segments of the river; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of fish for the Ohio River).

- Sustainable – the composite conditions for the selected indicators of ES for fish are such that diverse, healthy populations of fish are occurring along the majority of the river; further, the conditions of the indicators exceed regulatory thresholds or other pertinent measures.

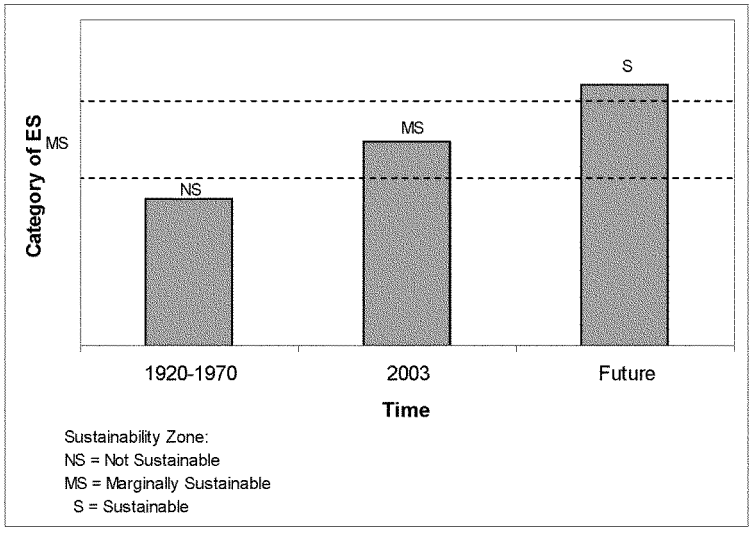
Based upon the above-described affected environment conditions, the consideration of multiple actions and their effects, the discussion of the connections with the two tiers of indicators, and the ES categories, the ES of the fish VEC of the mainstem of the Ohio River can be characterized and depicted in **Figure 4-2** as follows:

- In the time period prior to1920 and continuing well into the mid-20th century, fish communities became degraded, as reflected in the decline of many native river species and the increase in pollution tolerant species. This decline was particularly pronounced in the upper and middle river, where human populations grew rapidly during the first half of the 20th century, leading to increased inputs of domestic sewage, industrial effluent and acid mine drainage (especially in the upper river). Numerous other actions contributed to the degradation of fish communities, including, but not limited to, land clearing and sedimentation beginning in the 19th century, impoundment of the river by navigation dams that disrupted migrations of several important river fishes, in-stream sand and gravel dredging, development of new ports, terminals and marinas, the introduction of the common carp, and increasing quantities of stormwater runoff from urbanizing areas. Because these actions contributed to habitat loss, changes in species composition and abundances, and serious declines in necessary water quality conditions, the ES for this period is classified as "not sustainable." Further, until 1948, when a limited precursor of the Clean Water Act was passed and the ORSANCO interstate compact was signed, environmental and resource protection laws were limited. Accordingly, as a result of scientific data indicating changes in fish communities of the mainstem, as well as the recognition of multiple actions and factors causing such changes, it was concluded that the composite conditions for the selected indicators of ES for fish communities did not reflect conditions that would sustain diverse, healthy fish populations throughout the river.

- In the time period from the mid- 20th century until the present time, improvements in sustainability of the fish resource have been observed throughout the mainstem. Such improvements have resulted primarily from initiatives by ORSANCO, efforts of the six Ohio River states, and the requirements of the FWPCA and the amended

CWA. As municipal wastewater and industrial effluents to the river have decreased and other pollution control measures have increased pH and oxygen while reducing toxins, fish communities of the Ohio River have shown steady improvement, marked by the recovery of many native species. The common carp, while still significant in biomass and numbers, is no longer as dominant as in the past. Concurrent with improvements in water quality, however, has been the continued inundation of fish habitat not only from navigation structures constructed before 1950, but also from continuing construction and operation of additional high-lift dams (including Olmstead L/D at RM 964.6). The modern navigation system, combined with land use and flood control practices in the watershed, has caused the inundation and siltation of extensive areas with gravel substrate, preferred by many migratory fishes, especially in the lower river. Various studies on human impacts on Ohio River fishes, including studies on winter habitat and fish passage, underscore the need for additional research and development of resource management practices to gain a more comprehensive understanding of ES of the mainstem fish. Accordingly, the ES of the fish resource up to the present time is classified as "marginally sustainable." Two major uncertainties emerged during the last decade that may affect the fish resource into the future: first, the invasion of Asian carps upstream from the Mississippi River causing competition for feeding niches of native fishes and, second, the invasion and unknown population dynamics of zebra mussels, which seriously impact native mussels, an important food resource for many fish species.

FIGURE 4-2
ES of Fish Communities



- Regarding the long-term future, this study has identified 60 types of RFFAs ranked as having high or medium importance relative to CEs. These RFFAs include actions that change habitat, change disturbance regimes, change hydrological patterns, affect ecological services, and are related to population changes. During

recent decades, regulatory requirements and pollution control programs have been implemented that will benefit the fish resource, if continued into the future. Additional tools and studies that also should increase understanding of the ES of fish in the Ohio River mainstem include the NAVPAT habitat assessment model, the new ORFIn, and supplemental fish studies in accordance with proposed regulations related to §316(a & b) of the CWA. It is also expected that the ORFMT and USFWS Ohio River Valley Environmental Team will continue to be involved in fish resource monitoring and management. Given recent improvements in the resource, the development of new assessment tools, and the level of stakeholder interest, it is expected that fish communities of the Ohio River mainstem will attain a "sustainable" condition and may further improve with long-term elimination of combined sewer overflows (CSOs) and better control of nonpoint pollution, including regulation of stormwater runoff. The habitat effects of impoundment of the river are expected to persist into the future. However, adaptive management of the resource may produce measures that counteract such effects by benefiting habitat and enhancing interpool connectivity. An eminent concern is the invasion of Asian carps species moving upriver; however, effects on native fishes have yet to be demonstrated or quantified. Vigilance by ORSANCO and other resource agencies will be required to assess populations while potential measures to control these species are evaluated for the Ohio and other major river systems in the U.S.

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Chapter 5
MUSSELS

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5.2 IMPORTANCE OF MUSSELS AS CUMULATIVE EFFECTS INDICATORS

Freshwater mussels or bivalves are valuable as indicators of environmental health, as a commercial resource in the cultured pearl industry, and as a major component of worldwide freshwater biodiversity (Williams et al. 1993). Mussels are the river's natural filter system, and they play an important role in the breakdown/compartmentalization of organic matter as well as provide habitat for other invertebrates. They also help stabilize the river substrate. Historically, one of the most diverse assemblages of freshwater mussels in the United States occurred in the Ohio River mainstem, with upwards of 80 species reported for the free-flowing river (USFWS 2000). Some positive trends towards mussel recolonization in the upper Ohio River have been observed since implementation of the Clean Water Act (CWA) in the 1970s, although the return of obligate big river riffle species has been less successful. There are currently at least 54 species (Ecological Specialists, Inc. 2000) of native freshwater mussels in the Ohio River. Tributaries with

viable mussel populations also have been important to recolonization and sustainment of the Ohio River mussel resource.

Unfortunately, in spite of such recent encouraging trends, freshwater mussels, in general, in the Ohio River mainstem have drastically declined in recent decades due to compounding factors, including habitat modification and destruction, as well as increasing competition from nonindigenous species, especially the zebra mussel. At least three species are extinct and many more have been extirpated (USFWS 2001). Today five native mussel species still occurring in the Ohio River mainstem are listed as federally endangered. The decline in both populations and species diversity of freshwater mussels of the Ohio River is likely occurring in other freshwater mollusks and aquatic organisms (Williams and Neves, not dated) and is underscoring the need for conservation and restoration on the ecosystem and watershed levels.

Freshwater mussels feed on organic particles, algae, and minute plants and animals, which they siphon out of the water. Because of their limited mobility, adult mussels are subject to a variety of environmental factors that can restrict their distribution and reproductive success. Both mussels' limited mobility and relatively long life spans make mussel populations good environmental indicators. This chapter considers how cumulative effects of human use of the Ohio River have influenced mussels inhabiting the river, what impacts to mussels may be anticipated in the foreseeable future, and what measures could be undertaken to mitigate potentially adverse impacts to this historically important, declining resource.

5.3 OBJECTIVES AND SCOPE OF THE MUSSEL STUDY

5.3.1 Objectives

This chapter assesses the system-wide cumulative impacts (including effects of mussels of all likely major navigation improvements) along the mainstem of the Ohio River during the planning period from 2000 to 2070. Impacts on mussels directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the US Army Corps of Engineers (Corps) and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFAs. These future actions include the major navigation improvements identified in this study, other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies, non-governmental entities, and predictions of general economic expansion and development as well as regulatory changes.

The results of the Cumulative Effects Assessment (CEA) are intended to contribute to further discussion of:

1) the significance of the impacts of the RFFAs on the affected resources
2) the degree to which the proposed navigation improvements contribute to those outcomes, and
3) what constitutes sustainable conditions for freshwater mussels of the Ohio River mainstem

5.3.2 Geographic Scope

The geographic focus for mussel impacts includes the Ohio River mainstem, which is most directly impacted by operation and maintenance of the navigation system, and also includes lands along either bank of the Ohio River lying "between the bluffs." This "floodplain zone" is defined as the meander channel of the Ohio River and includes the 100 and 500 year floodplains as well as terraces of level land lying above these flood zones. Floodplain lands are considered in this assessment because mussel populations are affected by siltation and contaminants associated with construction, industry, agriculture, mining, and other land-based activities.

5.3.3 Time Frame

The established time frame for this project is 1920 to 2070. The earlier date approximates the initiation of the Corps' lock and dam construction activities on the Ohio River. The latter date approximates the end of the 60-year planning horizon encompassed by the Ohio River Mainstem Systems Study (ORMSS). Discussion of impacts on mussels requires some consideration of the condition of mussel populations prior to 1920. Freshwater mussels in the Ohio River had begun to decline as long ago as the late 1800s. Understanding factors that contributed to this decline over more than 100 years is important to discussion of how the lock and dam construction, operation, and maintenance activities contributed to subsequent changes in mussel populations.

5.4 ISSUES FROM SCOPING

A series of 12 public scoping meetings was held during the summer of 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or e-mail. A more detailed discussion of the scoping meetings is presented in Exhibits A and B of this report.

The meetings were attended by 185 persons and over 200 verbal comments were recorded from the question and answer sessions. These comments accounted for the large majority of input. Additional comments were obtained from 19 questionnaires and several letters that were submitted. Comments that directly or indirectly addressed mussels are presented in **Table 5-1**.

TABLE 5-1
Comments from Public Scoping Meetings

Direct Comments on Mussels	Relevance to Mussels	Total
Importance of including commercial dredging and associated permitting process in CEA	Elimination of mussels and habitat	2
Failure of barges to stay in designated shipping lanes	Potential damage to mussel beds by barge groundings	2
Increased spills and accidents potentially affecting aquatic life and impairing water quality	Potential loss of mussels and habitat	1

Direct Comments on Mussels	Relevance to Mussels	Total
Need to improve sediment and erosion control from public and private developments	Sediment blanketing of mussels and habitat	1
Need for long-term plan to address silt removal and prevent future sedimentation	Sediment blanketing of mussels and habitat	1
Damage/destruction of mussel beds and fish spawning areas	Reduction in mussel resources	4
Habitat damage caused by Corps permitted commercial sand and gravel dredging	Potential loss of mussels and habitat	1
Loss of unique sensitive species due to water quality problems and habitat modifications	Reduction in mussel resources	2
Need for Corps to coordinate with USFWS on threatened and endangered species issues	Preservation of sensitive mussel species	1
Effects related to 3 crayfish species, 2 fish species and 7 freshwater mussel species in IL	Preservation of sensitive mussel species	2
Need to prevent distribution of exotic/invasive plants and animals through USACE actions	Prevention of mussel reduction/elimination by exotic species, e.g., zebra mussels	1
Other Comments with Implications for Mussels	**Relevance to Mussels**	**Total**
Need for ongoing coordination and cooperation with concerned agencies and groups	Preservation of healthy freshwater mussel fauna	3
Need to consider Clean Water Act (CWA) Section 404 application approvals and resultant actions as direct USACE actions	Preservation of healthy freshwater mussel fauna	1
Importance of coordination of resources agencies in determining baseline conditions	Need to assess current mussel populations	2
Effects of Greenup L/D improvements on barge queuing	Potential reduction of damage to mussel beds	1
Cumulative effects of discharges to river may offset water quality improvements	Failure to attain water quality improvements to benefit mussel populations	4
Challenge to water quality presented by Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)	Failure to attain water quality improvements to benefit mussel populations	2
High levels of mercury, arsenic, fecal coliform bacteria and agri-chemicals in surface water	Failure to attain water quality improvements to benefit mussel populations	1
Need for more stringent discharge permitting procedures or moratorium on permits	Need for WQ improvements to benefit mussels	2
Possibility of implementing mechanical aeration in mainstem pools	Need for sufficient oxygen levels for mussels	1
Importance of continued water quality improvements as a high priority	Need for WQ improvements to benefit mussels	1
Mouths of tributaries silted in, impairing fish habitat, limiting access and damaging property	Elimination of habitat for mussels and their fish hosts	5
Impaired water quality and bioaccumulation in fish tissue of harmful substances stirred up by dredging	Uptake of toxic substances by mussels	2
Potential partnering with private enterprise to remove marketable aggregates when dredging	Continued elimination of mussels and habitat	1
Possible use of dredge spoils to improve riparian or island habitat or for upland filling	Potential creation of mussel habitat	2
Bank undercutting & failure caused by increased barge traffic, queuing and wave action	Sediment blanketing of mussels and habitat	7
Bank erosion caused by USACE-controlled pool fluctuations	Sediment blanketing of mussels and habitat	3
Development of floodplains and wetlands resulting in increased runoff and habitat loss	Failure to attain water quality improvements to benefit mussel populations	4

5.5 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY

Indicators of Environmental Sustainability (ES), which vary by VEC, generally provide benchmarks for measuring CE on a given resource or VEC. The primary uses of indicators are to characterize the current status of a resource and to track or predict significant changes to the resource. It is desirable to select indicators that can be supported by data that are relatively straightforward to collect. Further, if an indicator is to be accepted and used to guide policy, the data upon which indicators are based must be available to a wide range of interested parties (CGER 2000).

ES indicators selected for mussels encompass the essentials for diverse communities of mussels to thrive and reproduce in the Ohio River. Key indicators, therefore, include:

- amount of habitat with stable substrates, suitable depths, currents, and connectivity to other mussel populations
- measures of water quality parameters important to mussel populations
- extent of food supplies to help ensure good growth rates and reproduction
- availability of fish hosts to ensure reproductive success and maintain species diversity
- extent of disturbance from biotic stressors, such as invasive zebra mussels and from abiotic stressors, such as river traffic.

The entire suite of indicators may be essential to adequately characterize and track freshwater mussels. Watters (1999) and others indicate that the basic biology of mussels is much more complex than previously known. Consequently, there is rarely a single causative agent for mussel decline.

Shifts in mussel abundance and community composition are measurable using community-level summary statistics such as diversity indices and species richness. Quantitative mussel surveys, including invasive species and distribution studies of endangered species, are also useful assessment methods.

The severe decline of native Ohio River mussels documented in the last decades of the 20th century coupled with the more recent invasion of zebra mussels has focused considerable research on freshwater mussels. Information to assess the selected indicators of mussels includes data from the Corps and from studies conducted by USFWS and ORSANCO.

5.6 LAWS, REGULATIONS, ORDINANCES, AND PROGRAMS

Several regulatory actions and related initiatives influence mussel populations in the study area. **Table 5-2** presents information on important regulations and established programs, which directly or indirectly influence mussels in the Ohio River.

TABLE 5-2
Laws, Regulations, Ordinances, And Programs Relevant to Mussels

Law/Program (Lead Agency)	Key Components	Relevance to Mussels
Clean Water Act (US Environmental Protection Agency)	• Section 402 establishes National Pollution Discharge Elimination System (NPDES) for regulating pollution discharges into U.S. waters • Gives EPA authority to implement pollution control programs • Requires establishment of water quality standards • Recognizes need to address nonpoint source pollution	Protects mussels within general context of water quality improvements
Endangered Species Act (US Fish & Wildlife Service)	• Provides various means of protection for endangered and threatened species and their critical habitats • Provides process for designation of such species and their habitats • Encourages development of related state programs	Has enabled endangered species designation for five Ohio River mussel species and addition of other species to candidate list. State endangered species status further supports protection of these endangered Ohio River mussels.
Fish and Wildlife Coordination Act (US Fish & Wildlife Service)	• Requires that whenever water bodies are modified by a federal agency, that agency first shall consult with the USFWS and with appropriate state agencies with a view toward wildlife conservation	Provides for equal consideration and coordination of mussel conservation with other aspects of water resources development
COE Permitting Statutes (US Army Corps of Engineers)	• Section 10 of Rivers and Harbors Act (1899) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. • Section 404 of Clean Water Act authorizes the Corps to issue permits for the discharge of dredged and fill materials into U.S. waters.	Permits require assessment of impacts on water quality, mussels, and other aquatic resources and mandate mitigation of adverse impacts
State Water Quality Certification (Appropriate state or interstate pollution control agencies.)	Section 401 of Clean Water Act requires certification from state or interstate water control agencies that a project is in compliance with established effluent limits and water quality standards.	Provides opportunity for state or interstate scrutiny of impacts of such actions on mussels
Small Navigation Projects (US Army Corps of Engineers)	Section 107 of Rivers and Harbors Act (1960) authorizes COE to develop and construct small navigation projects for harbor protection	Provides opportunity for COE scrutiny of impacts of such actions on mussels
Site Remediation Statutes (US Environmental Protection Agency)	Includes CERCLA, RCRA, SARA and related state programs that focus on cleanup and restoration of contaminated sites	Potentially reduces soil and groundwater pollution sources which may adversely impact

Law/Program (Lead Agency)	Key Components	Relevance to Mussels
		mussels in the Ohio River
TMDL Program (US Environmental Protection Agency with ORSANCO)	Section 303 of Clean Water Act regulates the maximum load of a pollutant a water body can receive and still attain water quality standards	Presents a more holistic option to water quality management that may be more beneficial to mussels than traditional "command and control" approaches
Phase 1 & 2 NPDES Program (US Environmental Protection Agency)	Requires municipalities and certain industrial and construction sites to adopt BMPs to control nonpoint sources of pollution	Should reduce pollution characteristics of stormwater discharges from urban and industrial zones that may adversely affect mussels in the Ohio River
Spill Response (US Coast Guard, ORSANCO)	Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the Clean Water Act	Minimizes adverse impacts of spills and discharges on mussels and other aquatic life and water quality
ORSANCO Monitoring (ORSANCO)	Encompasses ongoing water quality and aquatic ecology monitoring programs by the Ohio River Valley Water Sanitation Commission	Helps track changes in biological communities of relevance to mussels and provides database for environmental decision-making
Kentucky Mussel Refuges Act (KY Dept. of Fish & Wildlife Resources)	Establishes sanctuaries near KY islands within Ohio River Islands National Wildlife Refuge	Prohibits commercial mussel harvesting and collecting from these refuges

5.7 LIFE HISTORY OF FRESHWATER MUSSELS

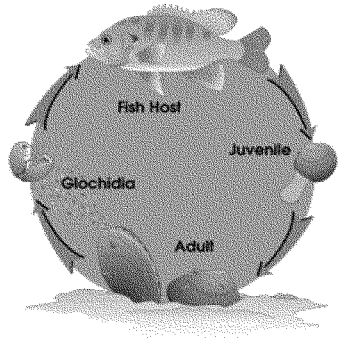
Important conditions must be met during each stage of the life history of mussels in order to sustain mussel populations in the Ohio River mainstem. Gametogenesis is stimulated by changes in water temperature. For fertilization to occur during the spawning season, sperm released by mature males must pass into the incurrent apertures of sexually mature females of the same species; therefore, a threshold density is required for reproductive success. After an egg is fertilized, it is transferred into the female's gill chamber where it undergoes metamorphosis from an embryo into the larval form known as the glochidium. Mature glochidia may be released after a few weeks or held in the brood chamber for months, depending upon the species. Bradytictic or long-term breeders hold

larvae until the following spring or summer. Tachytictic or short-term breeders release larvae later the same year, usually by July or August (Watters 1994).

The glochidia of almost all freshwater mussels are obligate parasites of fish and, consequently, must attach within 24 to 48 hours to the gills or fins of a suitable fish species to undergo another metamorphosis into free-living mussels. Fish may become infested with glochidia by coming into contact with them in the water column, on the substrate, or by attempting to ingest them, depending on the mussel species and where glochidia are released in the water column. Females of several mussel species mimic prey fish or insects to lure fish hosts before they release their glochidia. Other mussel species secrete a gelatinous matrix around the mature glochidia before they are released.

Once the glochidia have successfully attached to the fish host, they remain attached for a period of time that varies by species. While attached, the glochidia metamorphose into juvenile mussels, developing a true heart, gills, digestive tract, and muscular foot. When metamorphosis is complete, the juvenile mussel drops from the host and burrows into the substrate or attaches to a larger object by a byssal thread, secreted by a gland and later lost in adults. The buried juvenile stage may last for several years, according to several studies cited by Watters et al. 2003).

FIGURE 5-1
Life Cycle of the Freshwater Mussel



SOURCE : North Carolina Mussel Atlas http://www.ncwildlife.org.

An appropriate fish species must be present at the right time and place to serve as a mussel host. Some species, usually widespread and abundant, are able to parasitize many species of ecologically and phylogenetically interrelated fishes, including exotics. Other mussel species, usually localized and rare, rely on only a few fish hosts. Plans to conserve and manage rare and endangered mussels require specific knowledge of host-mussel associations. Hosts have been identified for most endangered mussel species in the Ohio River except for the orange-footed pimpleback (Watters, et al. 2003).

The extent to which navigation dams act as barriers to interpool movement of fish hosts is important in assessing cumulative effects on the Ohio River mussel resource. The

greatest factor affecting mussels in the mainstem Ohio River is habitat alteration resulting from impoundment by the high lift dams. Maintenance of the navigation pools creates year round slackwater habitat which has had and continues to have the most significant adverse affect on mussel resources. Much of the impounded habitat is no longer suitable for a diverse and healthy mussel community, nor will it become suitable in the foreseeable future. Watters (1999) indicates that inaccessibility of fish hosts to their respective glochidial parasites may cause otherwise healthy mussel populations to grow old and die without recruitment of enough juveniles to sustain these populations. Connectivity among mussel populations also is essential to maintain genetic diversity.

5.8 PAST TO CURRENT BASELINE CONDITIONS

5.8.1 Native Mussels

As long ago as the late 1800s, freshwater mussels had begun to decline in the Ohio River, primarily from direct habitat disturbances, as well as indirect effects of siltation, pollution, and contaminants associated with construction, industry, and agriculture (Taylor 1989). Harvesting of freshwater mussels for button manufacture began in the Ohio River in the 19th century and continued through the mid-20th century until the advent of plastic buttons which were less expensive and more easily manufactured. Mussel harvesting along the river, however, continued beyond the 1950s in response to the cultured pearl industry's demand for small mussel pellets to stimulate pearl growth. As late as the 1980s, 22 active commercial mussel harvesters were operating on the Ohio and Tennessee Rivers (Williams and Schuster 1989).

Because of limited mobility, mussels are subject to a variety of environmental factors that can restrict their distribution and reproductive success. Payne and Miller (1999) found that long-term stability of Ohio River mussel beds depends on clay, silt and sand deposited during seasonal low flows being removed by high flows without eroding underlying gravel and cobble. Changes in current velocity and direction associated with high-lift dams have had impacts on mussel beds. Deposition of silt as current velocity diminishes upstream of dams seems to particularly affect younger mussels, which are small enough to sink below the silt and suffocate. When lower level dams were in place, in many areas, the current followed the shoreline, washing mussel beds free of silt and mud. With the completion of high-lift dams, current positions changed, allowing greater deposition of silt (Williams and Schuster 1989).

Dams isolate upstream mussel populations from downstream ones and affect the distribution of fish hosts while also flooding habitat of many species typical of larger rivers. Numerous studies cited by Watters (1999) have shown that, almost without exception, rivers that have been impounded have lost or had changes in their mussel fauna. Mussels, in general, are most abundant in shallow water; relatively few species can tolerate impoundment depths. Inundated floodplains and tributary embayments created by impoundments typically have shallow mud or sand-mud substrates that support mussel species adapted to soft substrates instead of species better adapted to big river riffle habitat with coarser substrates. In recent decades, competition from the nonnative zebra mussel (*Dreissena polymorpha*) has further contributed to reductions in native Ohio River mussels. (See "Zebra Mussels and Other Invasive Species" below.)

Several federally-listed threatened or endangered species of freshwater mussels have not been recently found and are considered to be extirpated from the Ohio River mainstem. These include the white wartyback, cracking pearlymussel, rough pigtoe, winged mapleleaf, northern riffleshell, and catspaw. The ring pink may be present but no live specimens have been collected in recent years. The tuberculed-blossom pearlymussel once occurred in the Ohio River, but may be extinct. Also, although historical records indicate the dromedary pearlymussel once occurred in the Ohio River, definitive data are not available (USFWS 2000).

The five federally listed endangered native mussel species currently known to exist in the Ohio River mainstem are the fanshell, pink mucket, orangefoot pimpleback, clubshell, and fat pocketbook (see **Table 5-3** for scientific names and further information). Among the reasons for their decline listed in USFWS Recovery Plans are:

- Impoundment
- Channelization
- Habitat alterations (e.g., from channel maintenance dredging and sand and gravel mining)
- Nonpoint source pollution (e.g., agricultural and stormwater runoff)
- Point source pollution (e.g., from industrial sites and wastewater treatment plants) and
- Competition and damage from zebra mussels

Three additional historic Ohio River mussels are listed by the USFWS as candidate species – the sheepnose mussel (*Plethobasus cyphus*) found as recently as 1994 in the Newburgh and Markland pools, the spectaclecase (*Cumberlandia monodonta*) which may be extirpated from the Ohio River, and the rayed bean (*Villosa fabalis*). Candidate species are organisms for which the USFWS has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act (http://endangerd.fws.gov/candidates/).

TABLE 5-3
Endangered Mussel Species Inhabiting the Ohio River

Scientific Name (Year listed as federally endangered)	Common Name	Preferred Habitat	Reproduction/ Fish Hosts Occurring in the Ohio River	OR States in which Species is Listed*
Cyprogenia stegaria (1990)	Fanshell	Gravel substrate in medium to large rivers	Breeding period unknown Hosts: greenside darter, banded darter, logperch	OH, WV, KY, IN, IL Once widely distributed
Lampsilis abrupta (1985)	Pink mucket pearly mussel	Medium to large rivers with fast-flowing water and depths of 0.5 to 0.8 m Various substrates including silt to boulders, rubble,	Spawns from August to September and releases glochidia the following year from May to July Hosts: smallmouth, largemouth and spotted basses,	WV, KY, IN, IL Once widely distributed, but always considered uncommon

Scientific Name (Year listed as federally endangered)	Common Name	Preferred Habitat	Reproduction/ Fish Hosts Occurring in the Ohio River	OR States in which Species is Listed*
		gravel and sand	walleye	or rare
Plethobasus cooperianus (1984)	Orangefoot (pimple back) pearly mussel	Medium to large rivers with fast-flowing water at depths of 12-29 ft. Only edge of shell & feed-ing siphons are exposed Clean silt-free rubble, sand or gravel	Requires stable, undisturbed habitat for reproduction. Adult may live up to 50 years.	KY, IN,IL
Pleurobema clava (1993)	Clubshell	Clean, coarse sand and gravel in runs often downstream of riffles; cannot tolerate slackwater conditions, burrows beneath substrate, very susceptible to siltation	Females gravid from May to July; glochidia released same year. Hosts: Unknown, possibly small minnow and darters	OH, WV, KY, IN, IL Once widespread and common; range reduced by 95%
Potamilus capax (1976)	Fat pocketbook	Large rivers with fast-flowing water and stable substrates Most likely prefers habitat of silt, sand and clay	Females reported gravid in June, July, August & October Glochidia released next spring or summer Only known host: freshwater drum	KY, IN, IL

* In addition to federal listing, these states along the Ohio River list the species as endangered.
SOURCES: USFWS (2000); individual USFWS Recovery Plans (listed in chapter references), http://midwest.fws.gov; and
http://www.conservation.state.mo.us/documents/nathis/endangered/mucket.pdf

There are no recent records of live specimens of any federally-listed threatened or endangered species in the Ohio River mainstem upstream of Willow Island Dam, although Watters (2003) suggests the fanshell probably occurs in Dashields pool. Records of endangered mussels from Willow Island Pool downstream (including subfossil shells) are in **Table 5-4** below.

The Ohio State University Ohio River Mussel Database was queried to cross-reference pools where both endangered mussels and their fish hosts occurred. The coinciding data for the fanshell and pink mucket pearlymussel are presented in **Tables 5-5 and 5-6**. Also, the freshwater drum, a fish host for the fat pocketbook, has recently coincided with the presence of the fat pocketbook in the Myers and Olmsted Pools. The Mussel Database included no recent fish host/mussel coinciding pool data for the orange-foot pimpleback or clubshell. Four Ohio River fishes, however, have been recorded as hosts for clubshell glochidia – the central stoneroller, striped shiner, logperch, and blackside darter (Watters, et al. 2003).

TABLE 5-4
Records of Endangered Mussels in the Ohio River by Pool

Ohio River Pool	*Cyprogenia stegaria (Fanshell)*	*Lampsilis abrupta (Pink mucket)*	*Plethobasus cooperianus (Orange-foot pimpleback)*	*Pleurobema clava (Clubshell)*	*Potamilus capax (Fat pocketbook)*
Willow Island				SF[1]	
Belleville	1997[2] 1[3]	1991 1			
Racine	1998 4	SF	SF	SF	
Byrd		1993 1			
Greenup		1995 5			
Meldahl	1929	1914			
Markland	1997	1846		1846	
McAlpine				SF	
Cannelton	2000			1994	
Newburgh					
Myers					Since 1980
Smithland				SF	1994
Olmsted (including L/D 52 & 53)			2002		1991

[1]SF = sub-fossil shell
[2]Most recent year for sample reported in "good condition" (live or fresh dead).
[3]Total live organisms found in all samples, Meldahl Pool and above, 1969-1999.

SOURCES: Clarke (1995), ESI (2000), Payne and Miller (2002) and Watters (2003)

Table 5-5
Known Fish Hosts of the Fanshell (*Cyptogenia stegaria*) by Ohio River Pool

Ohio River Pool	Greenside darter	Banded darter	Logperch	Blackside darter	Central stoneroller
Belleville	1997*	1993	2000		
Racine	2001	2001	2001		
Meldahl	2001	1992	2001		
Markland	2000	2000	2001		
McAlpine			2001		
Cannelton			2001		
Smithland			2001	1969	1997

*All dates indicate most recent record.
SOURCE: Master Ohio River Mussel Database, Ohio State University (Watters 2003).

Table 5- 6
Known Fish Hosts of Pink Mucket Pearlymussel (*Lampsilis abrupta*) by Ohio River Pool

	Smallmouth bass	Spotted bass	Largemouth bass	Walleye
Ohio River Pool				
Belleville	2001	2001	2000	2000
Racine	2001	2001	2001	1999
Byrd	2001	1995	1995	2001
Greenup	2001	2001	1999	1999
Meldahl	2001	2001	2001	2001
Markland	2001	2001	2001	2001
McAlpine	2001	2001	2001	1968

*All dates indicate most recent record.
SOURCE: Master Ohio River Mussel Database, Ohio State University (Watters 2003)

5.8.2 Mussel Studies in the Upper Mainstem River Reaches

A total of 117 studies between Pittsburgh (RM 0) and Meldahl Lock and Dam (RM 436) have recently been compiled into a database that can be used by river users and managers (ESI 2000). Most of the studies (99 of 117) were conducted post-1990 and are dive studies. Prior to 1987, studies were limited to bank searches and brailing (dragging a brail along the river bottom for a given time or area). Diving yields more accurate samples in large, deep rivers such as the Ohio River mainstem.

Studies conducted since 1991 indicate that some species of mussels are colonizing the upper to middle Ohio River mainstem, reflecting in large part the revitalization the river has undergone in recent years due to more stringent water quality standards (ESI 2000, Cavanaugh and Mitsch 1989). Patterns in the ESI data suggest that recolonization is occurring primarily from downstream as evidenced by:

- decreasing species richness and abundance in more upstream pools, and
- opportunistic habitat use in upstream pools.

Mussels were completely extirpated from the upper portion of the Ohio River during the early 20th century. Ortmann (1919), in his classic monograph of the *Naiades* of Pennsylvania, reported the total demise of the mussel fauna of many tributaries of the upper Ohio River, mostly from the impacts of acid drainage from bituminous coal mining. However, in 1919 he was still able to document either the presence, or relatively recent occurrence, of a diverse assemblage of at least 39 species of mussels in the Pennsylvania portion of the mainstem Ohio River. As recently as 1980, Taylor found only subfossil shells and no living mussels in the Pennsylvania reach of the Ohio River. The recolonization of Dashields and Montgomery Pools by mussels as reported by Watters et al. (2003), therefore, is a very recent phenomenon.

The degree, extent, and duration of previous water quality conditions limiting to the survival of mussels along the upper Ohio River cannot be precisely determined from

historical data. However, as early as 1914, the U.S. Public Health Service documented episodic acidification of the Ohio River extending as far as 170 miles downstream of Pittsburgh (U.S. Public Health Service 1924). Data collected by the U.S. Geological Survey and the Pennsylvania Department of Forests and Waters (White 1951) provide a good picture of Ohio River water quality conditions (at a station 17 miles downstream of Pittsburgh) during the late 1940s. Cross-section measurements of total acidity between October 1947 and September 1949 ranged from 5 to 86 mg/l $CaCO_3$ and averaged 30 mg/l as $CaCO_3$ (N=24). The pH of the Ohio River ranged from 3.65 to 6.6 and averaged 5.3 (N=110).

Mussel beds (defined as areas where mussels are consistently found in greater abundance than in surrounding areas and where several species and young animals are present) occur as far upstream as Willow Island Pool (ESI 2000). However, recruitment in recent years was only apparent in a few areas in Willow Island Pool and density was low (<5 mussels /m^2). Density was still low to moderate (<10 mussels /m^2) between Belleville and Meldahl Pools, but species richness increased and recruitment was good in many areas sampled.

Table 5-7 includes the locations of mussel beds and other low-density areas in the upper river. Individual beds ranged from <0.5 mile to 5.3 miles long. Numbers of mussel beds generally increased from upstream to downstream pools. The larger number of beds in Meldahl Pool, however, may reflect the greater sampling effort there, especially relative to the Byrd (Gallipolis) and Greenup Pools.

ESI (2000) concluded that the present fauna of the upper Ohio River appears to be a mix of historical species and species that have recently colonized the study area from tributaries and downstream pools. Evidence of 54 species was found, including 35 species that appear to be part of the historical fauna and 19 species that have recently become established in the upper river. This considerably expands the number of species reported for the upper Ohio River by Taylor (1989). Of the 54 species for which evidence was recovered (including weathered and subfossil shells), one species is presumed extinct, eight species are considered extirpated from the study area and the status of two species is unknown. Ten species thought extirpated from the upper river, however, were found live or as freshly dead shells. Indications of recent recruitment were observed for 15 species, including five species previously thought extirpated. Increasing trends of total mussel species and rare mussel species (those species comprising <1% of the total collected) from upstream to downstream pools in the upper river are shown in **Figure 5-2**, further illustrating the downstream to upstream recolonization of the Ohio River mussel fauna.

Unfortunately, the invasion of zebra mussels (discussed in greater detail below) has occurred simultaneously with mussel recolonization of the upper river; and the full impacts of the invasion remain unknown. ESI (2000) concluded that without zebra mussel infestation, mussel communities would continue the trend of expanding distribution and increasing abundance, although species composition in the future may differ considerably from the historic fauna.

Table 5-7
Mussel beds and areas with scattered mussels in the upper Ohio River.

Pool	Bed no.[1]	Bank	Up. RM	Dn. RM	No. species in mussel bed	Density [2]	Recruit. [3]
Elmsworth							
Dashields							
Montgomery							
New Cumberland	A	LEFT	32.0	32.3	2	ND	ND
	B	IS LEFT	35.0	36.0	5	ND	ND
Pike Island	A	BOTH	55.0	57.5	1	ND	ND
	B	RIGHT	75.5	78.0	3	ND	ND
Hannibal	A	IS HEAD	89.0	89.5	1	ND	ND
	B	LEFT	96.7	97.3	1	ND	ND
Willow Island	1	LEFT	128.5	130.5	7	ND	Y
	A	RIGHT	128.5	130.5	3	ND	ND
	2	ISLAND	131.8	133.2	16	Low	0
	3	ISLAND	133.8	135.8	11	Low	Y
	B	LEFT/ISL	138.2	139.6	7	ND	ND
	4	LEFT/ISL	140.0	142.0	11	ND	ND
	5	RIGHT	140.0	141.0	6	ND	ND
	6	BOTH	150.0	151.0	9	Low	0
	C	ISLAND	151.5	152.0	8	ND	ND
	7	ISLAND	152.7	155.3	14	ND	ND
	8	BOTH	155.8	158.0	9	Low	ND
	D	ISLAND	158.3	158.5	1	ND	ND
Belleville	A	BOTH	162.0	168.0	4	ND	ND
	1	ISLAND	168.5	172.8	16	ND	Y
	2	ISLAND	175.0	177.5	30	Moderate	9 to 53
	3	RIGHT	179.0	180.0	18	ND	ND
	4	ISLAND	181.0	182.5	18	Low	37
	B	BOTH	183.0	183.7	11	Low	2
	C	ISL	186.0	189.5	14	Low	20
	5	RIGHT	192.8	193.3	15	Low	24
Racine	1	LEFT	204.4	208.8	25	Low	33 to 52
	2	RIGHT	204.5	207.7	23	Low	33 to 54
	A	BOTH	208.0	218.0			
	3	RIGHT	208.5	209.7	10	ND	Y
	4	RIGHT	210.6	215.9	20	Low	57
	5	LEFT	213.3	215.6	9	ND	ND
	6	LEFT	216.0	218.0	12	ND	ND
	B	LEFT	229.5	230.0	1	ND	ND
	7	ISLAND	234.9	235.0	9	ND	ND
Gallipolis	1	RIGHT	238.5	238.9	8	ND	ND
	A	BOTH	248.0	249.0	1	ND	ND

Table 5-7
Mussel beds and areas with scattered mussels in the upper Ohio River.

Pool	Bed no.[1]	Bank	Up. RM	Dn. RM	No. species in mussel bed	Density [2]	Recruit. [3]
	2	LEFT	252.3	252.8	16	Low	50
	3	RIGHT	253.8	254.1	15	Low	50
	4	RIGHT	254.5	255.5	18	Moderate	18 to 63
	B	RIGHT	256.5	258.4	4	ND	ND
	5	LEFT	257.4	258.0	17	Low	17 to 28
	C	BOTH	260.0	265.0	7	ND	ND
	D	LEFT	277.2	278.0	1	ND	ND
Greenup	1	RIGHT	282.5	282.7	9	Low	11
	2	LEFT	282.5	284.5	30	Low	20 to 30
	3	LEFT	286.4	288.8	26	Moderate	Y
	4	RIGHT	288.5	290.5	22	Low	Y
	5	RIGHT	292.0	292.8	21	Abundant	Y
	6	LEFT	299.8	301.0	16	ND	ND
	A	RIGHT	326.9	327.1	1	ND	ND
	7	RIGHT	332.0	332.3	13	ND	ND
Meldahl	1	BOTH	341.0	343.5	22	ND	Y
	2	LEFT	344.2	344.9	12	ND	ND
	3	LEFT	354.7	355.9	15	Low	56
	A	RIGHT	355.5	355.7	1	<Low	100
	B	RIGHT	358.0	358.2	8	ND	ND
	4	RIGHT	362.9	363.5	9	ND	ND
	5	LEFT	366.1	368.0	10	ND	ND
	6	RIGHT	370.0	370.3	9	ND	ND
	7	LEFT	371.2	372.2	11	ND	ND
	8	RIGHT	372.6	373.5	9	ND	ND
	9	LEFT	376.4	377.0	9	ND	ND
	10	RIGHT	383.4	386.5	10	ND	ND
	C	ISL HEAD	387.8	388.0	6	ND	ND
	11	RIGHT	391.0	394.5	14	ND	ND
	D	ISL HEAD	395.0	395.1	7	ND	ND
	E	ISLAND	395.0	396.5	5	ND	ND
	12	ISL TOE	396.7	397.1	19	Low	14 to 55
	13	RIGHT	396.7	397.1	19	Moderate	16 to 22
	14	RIGHT	397.5	399.1	8	ND	ND
	15	LEFT	401.5	403.0	3	ND	ND
	16	RIGHT	406.0	408.0	5	ND	ND
	17	LEFT	409.0	410.7	8	ND	ND
	18	RIGHT	412.1	413.0	10	ND	ND
	19	LEFT	415.0	415.9	9	ND	ND
	20	RIGHT	417.1	419.1	27	Moderate	2
	21	LEFT	422.2	423.0	7	ND	ND
	22	LEFT	430.5	431.1	7	ND	ND

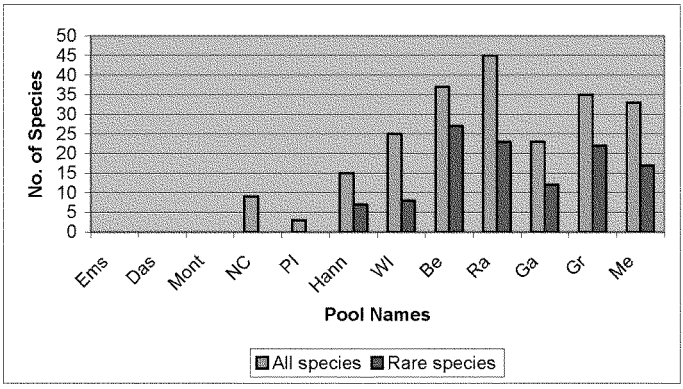
[1]Numbers designate beds (>0.4/m2), letters designate areas with density <0.4/m2, but more unionids than the surrounding area.

[2]Abundant, >10/m2; moderate, 5 to 10/m2; low, 0.4 to 5/m2; ND=no density data

[3]Range of % of individuals ≤5 years or ≤40mm, based on quantitative samples; if no quantitative samples then Y=individuals ≤5 years or ≤40mm collected, N=individuals ≤5 years or ≤40mm not collected. ND=no data available.

SOURCE: Upper Ohio River Mussel Database compiled by Ecological Specialists, Inc (2000).

FIGURE 5-2
Total and Rare (<1% of total) Mussels Species by Pool



5.8.3 Mussel Studies in the Lower Mainstem River Reach

The most comprehensive studies of mussels of the lower Ohio River mainstem have been conducted by Williams during 1967-1968, Williams and Schuster (1989), and Clarke (1995). During the last decades of the 20th century, several factors converged that stimulated these studies and underscored the importance of knowing the geographical locations of still-extant mussel beds in the lower Ohio mainstem. These converging factors included: 1) barge traffic on the river and the channel maintenance required to support it, 2) needs of the sand and gravel industry for in-stream areas to dredge, 3) heightened interest in conservation of native mussels, and 4) the increased importance of the mussel fishing industry (Clarke 1995). Further, these converging factors stimulated more site-specific mussel studies, including mussel research that has been conducted since 1983 in relation to the planning and construction of Olmsted L/D at RM 964.4.

Williams and Schuster (1989), whose studies during 1982 somewhat geographically overlap the ESI database discussed in the previous section, reported a net loss of 18.6 linear miles of mussel beds between RM 317 and RM 981 in the 15 years between 1967 and 1982. The most drastic change was the complete absence of mussel beds in 51.8 miles of the Ohio River above McAlpine L/D. According to Clarke (1995), Williams and Schuster found 78 mussel beds between RM 438.1 and 981 in 1976, but only 48 in 1982. Species composition also shifted during that time with the largest change occurring in the abundance of the ebony shell (*Fusconaia ebena*); this species comprised 16 percent of all mussels collected in 1967 and 26 percent in 1982. Between 1967 and 1982, four new high-lift dams within the study area (Cannelton, Newburgh, John T. Myers, and Smithland) replaced wicket dams while other high-lift dams completed during the 1960s had been operational for nearly 20 years. Williams and Schuster directly related decline in mussel bed area and species composition to the construction and operation of high-lift dams, concluding the two most important conditions impacting lower Ohio River mussels communities were:

- diminished current velocity from upstream to downstream portions of pools, causing silt deposition near dams that is especially detrimental to younger mussels and
- changes in current velocity and position relative to the main channel, contributing to silt deposition on mussel beds in quantities sufficient to decrease their areas or to eliminate them.

Clarke's 1993-1994 survey encompassed the lower reach sampled by Williams and Schuster more than decade earlier, but sampling conditions were different because of the invasion of zebra mussels in the interim. Clarke found only 40 of the 48 mussels beds reported by Williams and Schuster (1989) for the same reach, but delineated an additional five mussel beds not previously recorded in the literature. Clarke encountered heavy infestation of native mussels and bottom substrates by zebra mussels that severely interfered with sampling using wooden bottom brails and suggested these conditions accounted for failure to locate some of previously reported beds, especially in the Cannelton Pool. Of the missing beds, local informants told Clarke that one had been covered by sand and two others were overharvested to the extent that they no longer existed. Clarke found a total of 31 mussel species compared to 32 species found by Williams and Schuster. (See **Table 5-4** for locations where Clarke found the endangered clubshell and fat pocketbook and the sheepnose, a candidate species.) Because of sampling complications related to the zebra mussels, Clarke did not conclude that mussel beds were poorer in number of species or diversity in 1994 than in 1982.

Table 5-8 includes information on the beds located by Clarke (1995). The richest mussel bed in the lower river occurred near Owensboro, Kentucky, and contained 22 species including the candidate sheepnose mussel and rare rabbit's foot (*Quadrula cylindrica*). Clarke recommended designation of the bed as a nature preserve.

TABLE 5- 8
Mussel Beds in the Lower Ohio River between RM 438.1 – RM 981

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
Markland	Moscow North Bend	443.4	445.1	NA	
	California	446.7	447.3	NA	
	Melbourne	455.5	458+	NA	
	Little Sugar Cr.	522.2	522.7	NA	
	Bryant Creek	526.1	526.6	NA	
McAlpine	Vevay	537.7	540.0	NA	
	Brooksburg	549.5	554.7	NA	
Cannelton	Floyd-Harrison County	613.5	617.4	8	Expansion of nearby sand and gravel (s&g) dredging into bed would drive bed to extinction. In August 1994, zebra mussel invasion was well underway with an average of 40 zebra mussels attached to each

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
					unionid.
	Rosewood	625.5	627.6	6	Not near s&g dredging areas. In August 1994, zebra mussel invasion was well underway with an average of 5 zebra mussels attached to each unionid.
Cannelton (cont'd)	Haunted Hollow	650.9	Uncertain	11	Small bed of unknown shape. Not near s & g dredging areas. In 1994, contained Pleurobema clava (clubshell), a federal endangered species. In August 1994, zebra mussel invasion was well underway with an average of 50 zebra mussels attached to each unionid.
	Richardson Landing	652.7	Uncertain	10	Small bed of unknown shape. Not near s & g dredging areas. In August 1994, zebra mussel invasion was well underway with an average of 50 zebra mussels attached to each unionid.
	Leavenworth	664.3	665.0	16	Not near s &g dredging areas. Rich bed. In July 1994, on average 250 zebra mussels were attached to each unionid.
	Alton	679.2	679.7	5	Not near s &g dredging areas. Crowded zebra mussels with an average of 300 were attached to each live unionid.
	Cloverport	711.3	712.3	3	S & g dredging operations across river and upstream. Crowded zebra mussels with an average of 300 were attached to each unionid. Encrustation by zebra mussels com-plicated brail sampling.
	Millstone Creek	717.5	Uncertain	7	Not near s & g dredging areas.

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
					Bed being devastated by zebra mussels in summer 1994, with hundreds on each unionid.
Newburgh	(Town of) Cannelton	724.5	725.8	10	Across river from Fulton Bar, an area designated for s & g dredging. No zebra mussels observed in 1993, but present on nearby bed in October 1994.
	Hawesville	724.6	726.8	NA	Along opposite bank as Cannelton Bed. Located within Fulton Bar, an area designated for s & g dredging. In October 1994, on average about 30 zebra mussels were attached to each unionid.
	Troy	731.6	731.9	NA	
	Anderson Is.	734.2	735.4	NA	
	Lewisport	738.7	741.2	NA	
	Grandview-Rockport	742.2	747.1	NA	
	Puppy Creek	749.1	749.8	6	Downstream end of bed overlaps s & g dredging area. Another s & g area is across the river. In September 1994, on average 150 zebra mussels were attached to each unionid.
	Owensboro North	759.3	763.2	22	Richest bed in lower Ohio River, although located 300 ft. downstr. from s & g dredging area. Designation as a nature preserve recommended by Clarke. Very few zebra mussels observed in 1993; somewhat higher number (mean of 10) found in nearby area in 1994.
	Yankeetown	769.7	770.1	5	Downstream from s & g dredging area around French island and across river from such an area. Only one zebra mussel observed in 1993.
Myers	Green River East	783.0	783.1	6	Meets but does not overlap area where s & g dredging is permitted. No zebra mussels found

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
					in 1993.
	Green River West	784.8	785.0	7	Not close to s & g dredging area. Local fishermen describe bed as over-exploited for mussels. No zebra mussels seen in 1993.
	Dutch Island	796.7	798.2	14	Upstream and across river from s & g dredging area. In September 1993, only three zebra mussels were observed, one on each of three unionids.
	Henderson North	801.1	801.5	11	Not close to any s & g dredging areas. In August 1993, only one zebra mussel was observed.
	Henderson	803.7	805.4	9	Lies across river from long, narrow area where dredging is permitted. No zebra mussels observed in August 1993.
	Cypress Bend	813.0	815.1	11	Lies across river from s & g dredging area. No zebra mussels observed in August 1993.
Myers (cont'd)	Mount Vernon	852.2	852.2		Small bed is in shallow pools on Mount Vernon Towhead. Only juvenile mussels in 1-2 year classes found. Therefore, these pools may dry out some years. Not close to s & g dredging area.
	Uniontown	843.0	843.4	7	Not close to s & g dredging area. Remnant of much more widely distributed resource and biological assemblage. In September 1993, on average 22 zebra mussels were attached to each unionid.
Smithland	Old Shawneetown East	855.9	856.0	6	Does not overlap s & g dredging area, but about 1 mi. downstream from such an area. No zebra mussels observed in July 1993.
	Old Shawneetown	859.2	859.7	8	Parallels area of river where

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
	South				s & g dredging occurs. Bed described 10 years earlier by Williams & Schuster as >1 mi. long.
	Upper Cave-in-Rock	879.1	879.9	NA	Opposite Cave-in-Rock Island.
	Rosiclare-Elizabethtown	888.5	891.9	NA	
	Carrsville	893.0	894.2	6	Near s & g dredging area. No zebra mussels observed in July 1993.
	Shelterville	896.0	897.0	6	Does not intersect any s & g dredging areas, but located across river from such an area. No zebra mussels observed in July 1993.
	Rondeau Island	898.8	902.1	9	Does not intersect any s & g dredging areas. No zebra mussels observed in July 1993.
	Sisters' Island	909.3	909.5	3	Not near any areas where s & g dredging is permitted. No zebra mussels observed in summer 1993.
	Birdsville	913.9	914.1	6	Does not intersect any s & g dredging areas. Local fishermen describe bed as over-exploited for mussels for cultured pearl industry. In June 1993, up to 75 zebra mussels observed on specimens of *Megalonaias giantea* (washboard), but numbers on other species not noted.
L/D 52	Cumberland Towhead	Opposite RM 922.6 & Cumber-land RM 0.3	923.4	6	Does not intersect any s & g dredging areas, although large dredging area is located 0.5 mi. downstream. Only slightly impacted by zebra mussels as of October 1994 (average of 0.4 per unionid).
	Kinkaid Landing	930.5	930.5	4	Densities relatively low, but qualifies as bed. Across river from area dredged for decades. Only one zebra mussel found.
	Brookport	936.8	938.8	9	Does not intersect any s

Ohio River Pool	Bed Name	Upstream RM	Down-Stream RM	No. Species Present[1]	Notes/Comments[2]
					& g dredging areas. Zebra mussel invasion well underway by June 1994, with averages of 3 adults and 40 juveniles on each unionid.
L/D 53	Metropolis East	940.5	942.1	11	Does not intersect any s & g dredging areas. Zebra mussel invasion well underway by June 1994, with 1 or 2 adults and an average of 25 juveniles on each unionid.
	Metropolis	944.0	944.8	5	Does not intersect any s & g dredging areas. Zebra mussel invasion had begun by June 1994 with an average of 6.8 juveniles on each unionid.
	Little Chain	947.5	948.1	7	Does not intersect any s & g dredging areas. Possibly over-harvested. Zebra mussel invasion underway by summer 1994 with an average of 50 juveniles on each unionid.
Below L/D 53	Olmstead-America	965.0	971.9	6	Does not intersect any s & g dredging areas. Zebra mussel invasion underway by summer 1994 with an average of 50 juveniles on each unionid.
	Mound City	972.1	974.1		Confined to mid-river. Important to local fishing and mussel harvesting activities. Zebra mussel invasion just beginning in September 1994 –only one zebra mussel found.

[1] NA = data not available on number of species in mussel bed
[2] Notes and comments extracted from bed descriptions provided by Clarke (see below).
SOURCE: Clarke, A.H. 1995. Survey of mussel beds in the lower Ohio River. Prepared for the U.S. Army Corps of Engineers, Louisville District by Ecosearch, Inc.

On a site specific level, intensive mussel surveys have been conducted since 1983 in the lower Ohio River near Olmsted, Illinois, to assess the ecological effects of construction and operation of a new lock and dam at RM 964.4 that will replace existing Locks and Dams 52 and 53. Upon completion, the new Olmsted Dam will increase water levels by a maximum of 10 ft. in the pool above the dam for approximately 42 percent of the year (i.e., during periods of normal and low flow). In addition to upstream changes, navigation traffic patterns and hydraulics immediately downstream of the new dam will be altered.

These projected changes are of special interest with respect to their possible impacts on a dense, diverse mussel bed that occurs from approximately RM 966.7 to 969 and includes the federally endangered orangefoot pimple back mussel (*Plethobasus cooperianus*). A second mussel bed has been sampled upstream of Olmsted Dam near the Post Creek outlet at RM 956.5 (Payne and Miller 2002).

In contrast to Williams and Schuster (1989) and Clarke (1995), who reported 17 and 6 mussel species from the Olmsted bed, respectively, the intensive multi-year efforts of Payne and Miller (1997) have documented 32 species. As with other studies, Payne and Miller reported that *Fusconaia ebena* (ebony shell) heavily dominates mussels in stable shoals of the lower Ohio River. Despite being a species-rich mussel community, the Olmsted bed has low species diversity because of the high relative abundance of *F. ebena*. The mussel community at Post Creek outlet is similarly species-rich, but *F. ebena* is less dominant. Consequently, diversity indices for the Post Creek community are more moderate.

Good recruitment of juvenile mussels occurs at both Post Creek and Olmsted and appears to be correlated with river discharge conditions. Years with strong recruitment, including 1981, 1990 and 1998, have had remarkably similar hydraulic conditions that may have enhanced both the probability of successful attachment of glochidia to the gills of their fish host and the subsequent settlement of juveniles from fish (Payne and Miller 2002). The combined conditions of spring temperature rise and a marked rise in discharge from a lower than average seasonal value are appropriate signals for spawning migrations of skipjack herring, the host fish of ebony shell glochidia.

Mussel studies near Olmsted Lock and Dam are anticipated to continue until the completed navigation project has operated for several years.

5.8.4 Zebra Mussels and Other Invasive Species Affecting Native Ohio River Mussels

The progress of the zebra mussel invasion in the Ohio River has been studied since its first appearance in 1991. Zebra mussels most likely spread throughout the Ohio River by barge traffic (www.lrd.usace.army.mil/gl/wq_or.htm#zebra). Zebra mussels negatively affect native mussels primarily by smothering siphons, preventing valve opening and closure, and interfering with normal feeding and burrowing. Further, studies indicate living freshwater mussels are a preferred substrate for zebra mussels (Ricciardi et al. 1995). These adverse effects have been compounded in the Upper Mississippi River system when the shorter-lived zebra mussels die and rot creating sustained anoxic bottom conditions that are intolerable to native mussels and their fish hosts (USACE 2002). Within a short time, zebra mussels have critically impaired native mussels already threatened by habitat degradation, such that by 1998 native mussel mortality was approaching 40 percent at lower Ohio River monitoring sites (Morrison 1998).

A model developed by Ricciardi et al. (1995) predicted severe mortality (>90 %) of freshwater mussels within 4 to 5 years after the establishment of habitats that support zebra mussel densities of at least 6,000 /m^2. A cooperative of state, federal and private partners have tracked impacts of zebra mussels on the Ohio River since 1995. Data from the cooperative's fall 2001 survey approached Ricciardi et al.'s prediction of 90 percent or higher mortality of the native species at sampling stations near Aurora, Indiana (near RM

497) and Rosewood, Indiana (near RM 627) (Morrison, personal communication). The USACE (2002), however, reports that native mussels continue to successfully recruit in mussel beds in the lower Ohio River, despite occasional high densities of adult zebra mussels. The persistence of native mussels in the lower river appears to be related to substrate scouring which prevents extensive buildup of zebra mussel debris.

Population dynamics of zebra mussels in the Ohio River are yet to be determined, but are under continuing study by the cooperative team mentioned in the preceding paragraph. After high densities were observed in the late 1990s, zebra mussels markedly declined in the last few years. However, photos of Belleville and Meldahl L/Ds recently provided by Morrison and others indicate that zebra mussels again are on the rise.

Long-term measures to protect native mussels include hatchery rearing and subsequent reintroduction of presently endangered species, and efforts to add at least one more mainstem mussel to the federal endangered species candidate list. Additions to the candidate list also may include two Ohio River snails (*Lithasia* spp.), whose populations have been damaged by zebra mussel infestation.

Experiments on fish predation of zebra mussels in the Mississippi and Ohio Rivers indicate that although fish can reduce numbers of zebra mussels in the two rivers, current levels of fish predation seem insufficient to regulate zebra mussel densities because of their great reproductive capacity (Thorp et al. 1998). Similar findings were reported from experiments in Lake Dardanelle, Arkansas (Magoulick and Lewis 2002).

Zebra mussels also have colonized concrete, metal, rope and other materials at Ohio River locks and dams, but complications by zebra mussels in navigation operations have been minimal, in part because of proactive measures taken by the Corps. Such measures have included physical and chemical treatments to protect locks and dams, navigation vessels and water quality monitors; use of high power hoses and other similar equipment and scheduling of additional time to remove zebra mussels prior to diving inspections (www.lrd.usace.army.mil/gl/wq_or.htm#zebra).

A Biological Opinion (BO) issued by USFWS in 2000 for the upper Mississippi determined that operation and maintenance of navigation pool and project-dependent commercial barge transportation would facilitate continued existence of zebra mussels and impede the recovery and survival of the federally endangered Higgins' eye pearly mussel. Alterations to dam operations and substrates offer potential for managing zebra mussel infestations in the upper Mississippi and creating habitat for native mussels that is less susceptible to accumulation of zebra mussel debris. Some evidence suggests that native mussels adapted to riverine conditions have a competitive advantage over zebra mussels, which are adapted to more lake-like conditions (USACE 2002).

Native mussels of the lower Ohio have been resilient to invasions of the nonindigenous Asian clam (*Corbicula fluminea*). The high densities and complex age structure of the Asiatic clam appeared to have no adverse effects on native mussels in the Olmsted bed from 1983 to 1993. Since 1993, Asian clam populations have greatly declined and zebra mussels, which first appeared in the Ohio River in 1991, have replaced Asiatic clams as the nonindigenous bivalve of primary concern. The zebra mussel density near Olmsted L/D was 49,000 individuals per square meter in 1994, but was reduced to

5,000 per square meter in 1995. High zebra mussel densities in 1994 resulted in reduced growth of native mussels, but did not cause major declines in density of native mussels such as have occurred in the Great Lakes. It remains to be seen if zebra mussels can occur in sustained abundance in the lower Ohio at a density sufficiently high to have drastic effects on native mussels (Payne and Miller 1999).

Black carp (*Mylopharyngodon piceus*) is another serious threat to native Ohio River mussels. This Asian species escaped into the Mississippi River system during flooding in the 1990s and now threatens the Ohio River system. Black carp are molluscivores (mussel and snail feeders) which are likely to negatively affect native mussel and snail populations. Native fish, turtles, birds, raccoons, otters, and muskrats also are likely to be affected through competition for food. The USFWS is in the process of listing black carp as an injurious wildlife species, but this listing will only apply to future importation and interstate transportation of the species (http://southeast.fws.gov/hotissues/Black_Carp_FS.pdf). Additional information on exotic fish species of the Ohio River is found in Chapter 4, Fish Resources.

5.9 INTERACTIONS WITH OTHER VECS

Recent drastic declines in native mussel populations have contributed to increased scrutiny of numerous human activities that affect them. Several VECs influence the sustainability of mussel populations in the Ohio River, primarily in connection with mussel habitat.

Water quality improvements in various chemical and bacteriological parameters over the last half-century have generally been beneficial to mussels. As indicated in Chapter 3, "**Water Quality.**" dramatic increases in the number of river miles fully supporting the warmwater aquatic life use designation have occurred in the past 20 years, as water quality has continued to improve. At the same time, changes in sediment patterns near high-lift dams and continuing sediment input from land development, agricultural activities, and dredging have resulted in siltation that has impaired respiration, feeding, and reproduction of mussels throughout the Ohio River. The transformation of the free-flowing Ohio River into a series of more lake-like pools has influenced current patterns and distributions of mussels, extirpation of some species, and extinctions of some big river riffle species. The dams themselves may form barriers to fish movement, which might inhibit the distribution of mussel-specific fish hosts that are necessary to complete the mussels' life cycle.

River transportation and recreational boating have facilitated spread of the invasive zebra mussel. After large infestations of zebra mussels in the mid- to late 1990s, zebra mussels have declined in the Ohio River. The long-term effects of this exotic invader remain to be seen. Barge transportation with associated fleeting and mooring areas, terminals, and ports potentially damages mussel beds through groundings, spills, and wave action that cause bank erosion.

Declines in freshwater mussel populations also underscore the need to maximize the effectiveness of regulations and programs to protect mussels. Concerns about mussel declines have:

- influenced lock operation and maintenance (including zebra mussel control) and commercial navigation to mitigate the impacts of barge queuing, fleeting and storage, and dispersed traffic,
- heightened the need to identify mussel beds and potential bed sites and develop protection plans before new developments such as lock extensions, bridges, marinas, and floodplain conversions are initiated,
- influenced channel maintenance dredging practices and increased interest in using dredged materials to create new islands and sandbars and to restore eroded riparian areas,
- helped promote ecosystem restoration (ER) and other initiatives aimed at habitat conservation and restoration.

The Ohio River navigation system itself can be viewed as a potential tool for management of native mussels and other aquatic resources. In concert with management of upstream flood control reservoirs, navigation dams may offer some possibilities for manipulating river flows to minimize damage and improve aquatic habitats. Further studies may be warranted, as no studies on flow manipulation of the Ohio River have occurred to date.

5.10 RELEVANT ACTIONS AFFECTING MUSSELS

Of 73 ranked RFFAs, only seven were not ranked "high" or "medium" with respect to their potential importance to freshwater mussels. These high numbers of important actions seem to reflect both the precariousness of the mussel resource and recently enhanced efforts to protect it. In essence, the high importance placed on such a large number of RFFAs communicates that resource managers who ranked the RFFAs perceive any adverse impacts to freshwater mussels as important. Comments that accompanied many RFFA rankings indicated that it was the actual or potential proximity of the activity to mussel beds or other mussel populations that generated the importance rankings. **Table 5-9** presents the matrix of RFFAs that were ranked as high or medium importance to Ohio River mussels.

The relatively complex and somewhat obscure biology and ecology of mussels makes it challenging to comprehensively discuss relevant actions affecting them. Because mussels respond to multiple interrelated factors, it is difficult to examine any action in isolation or even groups of actions. Although this section considers RFFAs according to their primary effects, it should be understood that most actions have cumulative and/or synergistic effects. Bearing grouping limitations in mind, RFFAs affecting mussels are discussed below in the context of:

- Actions directly contributing to habitat degradation and instability
- Actions indirectly contributing to habitat degradation and instability
- Actions affecting reproductive success and community connectivity and
- Actions beneficial to mussels.

TABLE 5-9
Cumulative Effects Matrix for Mussels

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Mussels	Importance[5]
Navigation Investment Actions					
Lock Extensions/New Locks/Replacement or Rehabilitation	A	H	SL, E	x	H
L&D operation and maintenance	A	H	SL,E	x	H
Non-structural navigation improvements	A	H	SL,E	x	H
Dam replacement and rehabilitation	A	H	SL, E	x	H
Other Corps Actions					
Channel dredging/dredged material disposal	A	H	SL, E	x	H
Navigation aids - Construction & O&M	A	H	SL, E	x	M
Flood damage reduction projects					
dry dams, other projects off mainstem	A	M	E	x	M
channel modifications	A	H	E	x	H
nonstructural (e.g., relocation)	A	H	E	x	H
Emergency streambank stabilization (Sec. 14)	A	H	SL, E	x	H
Modification of Corps structures for envt. improvements (Sec. 1135)	A	H	E	x	H
Ecosystem restoration of aquatic ecosystems (Sec. 206)	1,2	H	E	x	H
ERP Projects - 5 categories	A	H	E	x	H
Port development (Sec. 107) and maintenance dredging	A	H	SL, E	x	H
Pool maintenance	A	H	E	x	H
"But for Actions"					
Commercial Navigation					
barge queuing	A	H	SL,E	x	H
fleeting areas/barge storage	A	H	SL, E	x	H
terminals	A	H	SL, E	x	H
multi-modal sites	A	H	SL, E	x	H
increased traffic	A	H	E	x	H
dispersed barge traffic	A	H	E	x	H
barge/tow tech/"green" design	A	H	E	x	H
accidents/spills	A	H	E	x	H
Coast Guard Nav. Aids - Construction, O&M	A	H	E	x	M

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Mussels	Importance[5]
Instream sand and gravel mining	A	H	SL, E	x	H
Floodplain sand and gravel mining	A	H	SL, E	x	H
Limestone aggregates mining	A	H	SL, E	x	M
Coal utilities	A	M	SL, E	x	H
Other coal industries	A	M	SL, E	x	H
Hydropower on dams	A	M	SL, E	x	H
Water intakes	A	H	SL, E	x	M
Industrial users, excluding coal-related	A	H	SL, E	x	M
Recreation facilities - Construction and O&M	A	H	SL, E	x	M
Actions by Others					
Public lands acquisition and management	A	H	SL, E	x	M
Floodplain development					
residential	A	H	E	x	H
commercial	A	H	E	x	H
industrial	A	H	E	x	H
Crossings					
bridges	A	H	SL, E	x	H
utility	A	H	SL, E	x	H
industrial	A	H	SL, E	x	H
Riverbed crossings	A	H	SL, E	x	H
Marina development & operation	A	H	SL, E	x	M
Silviculture	A	H	R	x	H
Agriculture	A	H	R	x	H
WWTP discharges					
municipal	A	H	U	x	H
industrial	A	H	U,R	x	H
onsite systems	A	H	U,R	x	H
Stormwater discharges	A	H	U,R	x	H
Casinos	A	M	SL	x	L,M,H
Hazardous waste sites	A	M	SL	x	M
Regulatory Environment					
Phase I & 2 NPDES program	A	H	SL,E	x	H
TMDLs	A	H	E	x	H
Site remediation	A	H	SL,E	x	M,H
More stringent quality standards for environmental media	A	H	E	x	H

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Mussels	Importance[5]
Pollutant source control	A	H	E	x	H
Carbon sequestration	A	M	R	x	H
Farmland preservation	A	M	R	x	H
Effluent trading	A	H	SL,E	x	H
Agricultural discharges	A	H	R	x	H
Pollution Prevention	A	H	E	x	H
Emissions trading	A	H	SL,E	x	H
Corps permitting programs	A	H	SL,E	x	H
Small navigation projects	A	H	SL,E	x	H
ORSANCO monitoring program	A	H	E	x	M
Spill response	A	H	E	x	M
Environmental Awareness Education	A	H	E	x	H
ESA (Endangered Species Act)	A	H	E	x	H
Environmental sustainability practices	A	M	E	x	H

[1] Reasonably Foreseeable Future Actions
[2] Time period in which the RFFA may occur: 1 = within 10 years. 2 = in 10 - 25 years. 3 = in 25 - 60 years. A = applicable to all time periods
[3] Occurrence probability or likelihood RFFA will happen: H = high M = medium L = low
[4] Location or setting on river where RFFA is expected to occur: U = upper (Pittsburgh - Huntington), M = middle (below Huntington - Louisville), L = lower ((below Louisville - mouth), E = along entire length of river, SL = specific location, e.g., locks and dams, U = urban setting, R = rural setting
[5] Importance of RFFA: H = high M = medium L = low

5.10.1 Actions Directly Contributing to Habitat Degradation and Instability

This group includes actions that physically alter mussels and their habitats by direct damage or removal of mussels. Such actions also may indirectly alter habitats. Channel maintenance dredging and in-stream sand and gravel mining exemplify actions with both direct and indirect impacts.

Channel maintenance dredging (H) involves the removal and disposal of sand and gravel deposits from the navigation channel of the Ohio River to maintain a nine-foot depth. Mussels and other bottom-dwelling aquatic organisms may also be removed during dredging. Land disposal has been used for dredged materials in the upper 120 miles of the river, but past practices in the remainder of the river have generally utilized in-stream disposal (Rieger, personal communication). In-stream disposal of dredged materials potentially results in the disturbance of mussel beds through the redistribution of sediments, which may cover mussels and interfere with respiration and feeding. Sediments from dredging also may resuspend contaminants, increase concentrations of plant nutrients, lower or increase photosynthesis and increase biological oxygen demand (Watters 1999). The elimination of suitable habitat, destabilization of bottom substrates

and the creation of deep pools can inhibit recolonization of dredged areas (Kanehl and Lyons 1992). Recommendations for mitigating the adverse impacts of channel dredging include:

- Restricting dredged areas to the minimum required to maintain the navigation channel,
- Conducting long-term monitoring of mussel habitats where dredging has occurred and/or continues, and
- Disposing of dredged materials in a manner least harmful to mussels (e.g., land disposal, deep channel), and
- Creating new islands or riparian habitat (e.g., using structural fill for ER streambank restoration projects).

Potential future constraints on in-stream disposal may encourage land disposal of these dredged materials. In some cases, dredged materials may be utilized to create new sandbars or islands that would provide more sheltered habitat for mussels. For most extended reaches of the Ohio River, channel maintenance dredging is an ongoing activity.

Ongoing in-stream sand and gravel mining (H) also involves the removal of sand and gravel deposits from the river and their subsequent transport to land. Like channel maintenance dredging, this activity potentially results in disturbance and/or destruction of mussel beds and redistribution of sediments, which may cover mussels and interfere with metabolic processes. Further, a process called headcutting may occur following dredging, leading to the loss of habitat and mussels upstream from the dredged site. Headcutting occurs when the upper boundaries of a modified area collapse, moving the disturbance upstream in a zipper-like fashion (Watters 1999). Prohibiting instream mining activity in or nearby, known, well-marked mussel beds would help protect the Ohio mainstem's limited mussel resources and enhance their recovery.

Construction of lock chamber extensions (H) could require dredging and excavation in the Ohio River which could result in destruction, partial loss, or siltation of existing mussel beds or potentially suitable mussel habitat in proximity to the construction area. As described above, dredging would temporarily increase turbidity and suspended solids and might release any contaminants found in the sediments, though elutions of worst case contaminated sediments from the upper Ohio River failed to release priority pollutants (USACE 1982 and 1989). Increased sediments in the water column would harm benthic organisms, including mussels that are filter feeders. Construction also would require placement around the foundations of extended walls of fill consisting of concrete, rock, and earth (removed from the existing structure during demolition). Dewatering of auxiliary lock chambers to install additional filling/emptying systems would temporarily increase turbidity in the water column.

Construction of lock chamber extensions also could require establishment of parking and maintenance areas for equipment, a lay-down yard for materials, an onsite-disposal area for excavated materials and some earthwork where portions of the lock chamber connect with the riverbank. These activities would require clearing of vegetation with potential surface runoff and soil erosion that could lead to siltation of mussel beds.

Barge queuing upstream and downstream of locks and dams is expected to increase during temporary closures of main and/or auxiliary chambers, if lock chambers are extended. Queuing (H) would create turbidity and potential damage to mussel beds, as well as to fish spawning beds and other shoreline habitats while barges await lock passage.

The potential extent of impacts during all aspects of lock extension would vary at construction locations and in queuing areas depending upon their proximity to mussel beds. Several actions, however, could be taken to minimize or mitigate impacts including:

- Installing markers around shallow mussel beds in the vicinity of lock chamber construction areas.
- Installing mooring facilities that restrict queuing tows to the navigation channels, thus avoiding direct physical damage to mussel beds.
- Keeping barges away from sensitive mussel beds by utilizing various traffic management measures that would reduce queuing (e.g., use of helper boats, lock scheduling with remote mooring, queuing fees/penalties, etc.).
- Installing turbidity curtains to surround construction areas.
- Using environmentally acceptable fill materials.
- Scheduling construction to minimize in-river activities.
- Scheduling construction to avoid mussel breeding periods.
- Using dewatering techniques that minimize suspended solids in the water column.
- Implementing erosion control plans that emphasize phased clearing, containment of soils, water detention, and temporary reseeding of cleared sites along with timely permanent revegetation.
- Creating new side channel habitats with continuous flow and suitable substrate below dams.
- Disposing of dredged materials in a way that either does not affect mussels or creates new aquatic habitat.

Barge queuing during normal commercial navigation and its attendant turbidity effects and potential physical damage to mussel beds would be reduced during normal navigation operations, as a result of increased lock capacity and decreased lock maintenance events. However, barge fleeting and storage (H), which also may cause direct damage to mussels, would not be relieved by lock expansions and, in fact, would be expected to increase in proportion to growth of commercial traffic. Prohibiting fleeting and storage near mussel beds would help mitigate physical damage. Enhanced knowledge of mussel beds and good cautionary signage would be essential to restricting traffic in sensitive mussel areas, particularly in the absence of wildlife enforcement officers. An example of such an effort is the Biologist on Board program, a cooperative initiative between the USFWS and the towing industry, designed to promote communication among the participants and enhance education regarding aquatic habitats in and along the Ohio River.

Ongoing commercial use of lock and dam facilities requires periodic upkeep and maintenance, which includes major and minor repairs of both primary and auxiliary locks. As existing locks age, the need for such repairs will become more frequent. The frequency of repairs will generally increase as locks age and in proportion to increases in commercial traffic (and resultant use of the lock chambers) on the Ohio River. For the 60-year study

period, scheduled repair events are expected to occur on an average of once every five years for each lock and dam project (USACE 2000).

Impacts on mussels will vary depending upon the location and extent of each lock repair event. Dewatering of lock chambers, establishment of areas for equipment, parking and materials, and barge queuing as a result of delays at locks would all potentially impact mussels in the work area. These impacts could be lessened through the corresponding actions listed under lock chamber extension in the previous section.

Unlike lock extensions, maintenance and repair activities are not expected to require disposal of significant quantities of dredged or excavated materials. Also, zebra mussel control is expected to be part of lock maintenance and can lengthen a repair event.

Maintenance and repair events will occur with or without lock extensions. Completion of lock extensions or lock additions, however, can reduce repair activities and associated impacts to mussels in three ways:

- It may be feasible to schedule each construction project to eliminate one complete auxiliary chamber repair event or major rehabilitation that would have otherwise been necessary.
- Each extension creates a lock in new condition, allowing for a longer time interval between the auxiliary chamber repair events.
- Finally, the original full-sized lock will be used less, since total lockages can be shared equally between the two full sized locks allowing for a longer time between the main chamber repair events (USACE. 2000).

Fewer repair activities lead to reductions in queuing, especially important in the more ecologically sensitive tailwater areas subject to queuing of tows bound upstream. If locks are extended, impacts on mussels directly attributable to maintenance and repair activities will be reduced in proportion to the expected reduction in repair activity.

Effects from major lock rehabilitation (H) would be similar to those of repairs, but would likely occur over longer time periods.

Regardless of whether or not locks are extended, continuing operation of existing locks and dams (H) along the Ohio River and related pool maintenance (H) will have ongoing effects on mussels. These effects include siltation, modification of current direction and velocities, increased depth, downstream scour that may preclude recolonization, colonization of locks by zebra mussels, and restrictions on movements of fishes that host the glochidial stages of freshwater mussels.

An infrequent action with potentially significant impacts on mussels is major rehabilitation of the dams (H) (as opposed to rehabilitation of lock chambers). While the timing of rehabilitation projects is subject to numerous variables, this activity primarily corresponds to the useful life cycle of the dam. Of the 20 dams currently on the river, 6 have been rehabilitated in the past two decades, at an average age of 60 years following their initial construction. Assuming a life cycle of 60 years, all of the dams currently on the Ohio River may require major rehabilitation during the 60-year cycle of the study period.

Impacts related to mussels from dam rehabilitation projects would be similar to construction site impacts described previously for lock extension projects. The activities would require similar temporary impacts for construction parking and lay down yards and would likely entail similar needs for the disposal of dredged materials.

Port development and maintenance (H) is another activity with potentially adverse direct impacts on mussels. Awareness of the location of mussel beds, care in avoiding them, and use of turbidity curtains to limit downstream siltation are among measures that can mitigate such impacts. Development of new terminals and multimodal sites associated with commercial traffic would be expected to similarly impact mussel resources of the Ohio River. Avoidance of important mussel habitat at new sites and careful adherence to the Corps' permitting procedures (Section 10, and 404 and corresponding state 401 certification in connection with the Corps permit) would help to minimize these impacts.

Recreational activities, especially development and maintenance of marinas and boat launch ramps (H) and other support facilities, also can directly impact mussel resources of the Ohio River. Potential impacts of marina development include direct elimination or encroachment on mussel habitats and erosion and resultant sediment damage to mussel beds, unless turbidity curtains or other containment procedures are used during construction. Marinas tend to be located in embayments and can be found throughout the floodplain, although they concentrate somewhat in proximity to urban areas. The embayments in which marinas and related facilities concentrate comprise a very limited resource within the Ohio River floodplain. Additionally, dredging activity within these embayments is generally required to maintain accessibility to the marinas and/or launch ramps. The expected continued growth of marinas and dredging of embayments will likely compete with or displace other resource values of the embayments, including known or potential mussel habitat and other aquatic resources. Other facilities supporting boating and non-boating activities include riverfront parks, riverfront hotel/restaurant complexes, and casino boat/resort complexes. Virtually all recreation infrastructure has been built in relation to and is dependent upon continued maintenance of the existing system of navigation pools. Careful recreational facilities siting and other protective measures would help prevent further habitat loss to mussels in proximity.

Dispersed barge traffic (H) outside of designated shipping lanes is not frequent, but also may result in direct damage to mussel beds.

5.10.2 Actions Indirectly Contributing to Habitat Degradation and Stability

This group includes actions that indirectly alter and destabilize mussel habitat. Such actions also may affect reproductive success and community connectivity. As Watters (2003) explains in more detail, impoundment necessary for continued operation of locks and dams along the Ohio River dramatically reduces mussel habitat heterogeneity and buries the original channel under deeper water. Suspended sediments reduce light penetration and associated algal production that provides food for mussels and leads to oxygen depletion and reductions in growth. After impoundment, sediment deposition impacts the original mussel fauna which may be eliminated or greatly reduced in favor of invading species are better adapted to softer substrates.

Channel modifications designed to reduce flooding (H) also affect flow patterns, which in turn may cause changes in species composition of mussel beds either through sediment deposition or natural scouring. Existing and increased barge traffic (H) creates another type of scouring – propeller-induced scouring (prop scour) from large vessels. Further, barge traffic continues to spread zebra mussels and has the potential to destroy juvenile mussels, thereby limiting reproductive success. Watters' (1999) review of the effects of hydrologic and instream habitat alterations on mussels, however, included conflicting results and suggests that further studies are warranted. Aldridge et al. (1987), as cited by Watters, concluded that frequent turbulence (once every 0.5 hr) and high concentrations of suspended solids (600-750 mg/L) significantly changed the food clearance rates, oxygen uptake, and nitrogen elimination of mussels. In contrast, Miller and Payne (1995, as cited by Watters 1999) concluded that changes in velocity associated with barge passage were too small and too short in duration to affect mussels.

Floodplain sand and gravel mining (H) and limestone aggregate mining (M) do not involve direct riverbed extractions that could damage mussel beds. These mining activities, however, benefit directly from the availability of barge transport along the Ohio River and may entail the construction and maintenance of port/docking facilities with potential impacts on mussels. As with general terminal construction discussed in the previous section, facility siting to avoid mussel beds and compliance with associated Corps permits is important in reducing construction and operation impacts.

Well-documented improvements in water quality in the Ohio mainstem since the mid-20th century have benefited mussels and other aquatic life, but some pollution threats remain. For example, spills of hazardous materials during navigation and product transfer (H) can threaten mussel beds and other aquatic resources, although advanced spill notification systems, Coast Guard spill reporting procedures, and improved containment and recovery techniques have ameliorated these impacts in recent years.

Another potential future mining related impact to mussels along the upper Ohio River is acid mine drainage (AMD) from abandoned coal mines. As discussed earlier in this chapter, along with uncontrolled industrial and domestic waste pollution for most of the 20th century AMD totally eliminated mussels from the upper Ohio River. For the past three decades, drainage from both active deep mines and associated interconnected abandoned mines has been pumped and treated. This pumping and treatment has resulted in highly improved water quality and previously extirpated mussel species, and other aquatic life, have made progress in recolonizing the upper river. At present, however, a series of huge underground mines in the Pittsburgh Coal Seam are facing bankruptcies and closures. Unless actions are taken to mitigate this problem, these mines will soon flood and discharge enormous quantities of untreated AMD. The mines with the greatest potential to degrade the Ohio River will discharge along a 100-mile reach of the left descending bank of the Monongahela River. Of special concern will be the extremely degraded first flush from each mine complex. First flush discharges could be months or years in duration for each mine. As of this time, there is no well-developed plan, authority, or source of funding to address this problem.

Industrial discharges to the Ohio River are highly regulated under the NPDES permitting program of the CWA, but spills, NPDES violations, and discharges of unregulated substances may still occur with potentially harmful effects on mussels and

other aquatic life. Other potential mussel impacts related to industrial activities (M) along the river primarily focus on transfer of potentially harmful materials and maintenance of port/docking facilities. Coal transport alone currently accounts for more than 55% of all barge traffic on the Ohio River and is projected to account for a large percentage of traffic for the foreseeable future. Because of the coal industry's prominence, potential impacts on mussels from barge activities and spillage of coal fines and other harmful substances are particularly important. Contaminated sediments from past industrial pollution or landfill materials can impede mussel recovery wherever such sediments occur, but they are more prevalent in the heavily industrialized upper river.

Floodplain ordinances, government programs and other constraints have limited **residential, commercial, and industrial development (all H)** in the Ohio River floodplain in recent years; however, some floodplain development is expected to continue throughout the study period. Possible impacts related to mussel populations include increased erosion and attendant siltation during construction and increased stormwater runoff and associated pollutants as impervious surfaces, such as driveways, parking lots, and roof tops increase. Phase 1 and 2 stormwater programs over time, however, should decrease stormwater impacts. (See Exhibit D, Land Use, for additional details.)

Bridge construction, redesign, or replacement (H) is expected to be a relatively infrequent occurrence during the time frame of this study. Bridges can potentially affect mussel beds because of erosion and siltation during construction and possible long-term alterations of flow patterns, which in turn can cause velocity changes and silt deposition on mussel beds. Drastic flow alterations can even lead to disappearance of entire habitats as occurred at Baker Island (formerly located at RM 49.5) (USFWS 2001). A comparison of 1987 and 2003 Pittsburgh District navigation charts documented the scouring away of Hughey Island (formerly at RM 9.0 near Neville Island) following construction of the Interstate 79 bridge piers just upstream. Available GIS data on mussel beds should be consulted during bridge planning to determine if mussel beds are present and to ensure that necessary preventive measures are undertaken. Additionally, bridge design can determine if materials spilled on the bridge will enter the river directly or be diverted to the shore where they might be contained more easily.

Other utility, industrial, and riverbed crossings (H) will occur more frequently during the study period than bridge construction. Such crossings may involve suspending aerial lines or burying lines beneath the river bottom. As with bridges, care in avoiding mussel beds in proximity to the crossing and measures to limit turbidity and siltation would limit potentially adverse impacts. Another pertinent aspect of riverbed utility crossings is that, along with buffer zones, they are protected from commercial sand and gravel dredging activities. Thus, some older utility crossings may inadvertently serve as mussel refuges.

Agriculture (H) and silviculture (M) constitute the largest land use activities by area within or adjacent to the Ohio River floodplain. These activities potentially impact mussels primarily through erosion and runoff, which carries sediments and associated pesticides and herbicides. Voluntary implementation of BMPs promoted through the USDA helps mitigate these impacts, but such BMPs are not uniformly used. Most future conversions of land use in the Ohio River corridor will occur on land currently in agriculture or in forests with potential impacts to mussels as described under floodplain development.

5.10.3 Actions Affecting Reproductive Success and Community Connectivity

This group includes actions that inhibit or prevent normal reproduction and actions that cause isolation of mussel communities.

As previously mentioned, impoundment associated with the Ohio River navigation system has lead to siltation of the river channel that not only has interfered with feeding and respiration, but impoundment may also reduce or stop reproduction and growth (Watters et al. 2003) and downstream scour that may preclude recolonization. A 1993 study cited by Watters (1994) noted that fertilization success may be related to population density, with a threshold density required for any reproductive success.

Already declining Ohio River mussel communities were further weakened and isolated after the arrival of zebra mussels in the mainstem in 1991. Because watercraft provide attachment sites for zebra mussels, the rapid spread of this invasive species has been facilitated by the movement of commercial barges, power boats, and personal watercraft (PWCs) throughout the system. Barges are the major vector because of their large surface areas and time in the river.

Numerous studies have shown that even low level dams may affect movement of fish hosts and thus restrict the ranges of some mussels. Under high flow conditions, some fish hosts may be able to traverse dams, but unless high flows occur in late spring or summer when glochidia are released, high flow fish passage will not help interpool mussel dispersal. Watters et al. (2003) indicated that declining mussel populations in the Ohio River mainstem do not seem to be attributable to loss of fish hosts. While several host fish species were extirpated in the upper river, most pools have a wide variety of fishes that could act as hosts, particularly in the middle and lower river pools. In fact, the number of fish species by pool has increased as water quality has improved since the mid-20th century. Watters et al. (2003) concluded that while it is possible that some very specific mussels, perhaps now extinct, may have been affected by the loss of proper fish hosts, those are probably exceptions.

5.10.4 Actions Beneficial to Mussels

This group includes traffic management and regulatory actions that directly or indirectly benefit mussels and their habitats and act as countermeasures to the cumulative effects of many previous listed RFFAs.

Within this grouping, nonstructural navigation improvements (H) constitute non-regulatory actions perceived as having high importance to mussel resources. Nonstructural navigation improvements refer to traffic management alternatives that do not involve modifications of lock and dam infrastructure. Because these nonstructural measures can facilitate passage of barge traffic, barge queuing and related siltation and physical damage to mussel beds are reduced. Nonstructural navigation improvements include efficiency measures, such as vessel scheduling and prioritization and self-help coordination among towboat coordinators. Related structural measures, such as expanded mooring facilities near locks and dams, may result in modest, temporary riverbed and/or land-based impacts during construction and installation. Using BMPs for sediment and erosion control and

avoiding construction of mooring facilities within or adjacent to existing mussel beds or potentially suitable habitats should help minimize impacts. Other nonstructural measures such as vessel scheduling may require improved communication and position tracking system, which are expected to have no direct environmental impacts. Further information on nonstructural measures is found in Chapter 10, Transportation.

Table 5-1 (in the section titled Laws, Regulations, Ordinances, and Programs) presents ten regulatory actions relevant to freshwater mussels. The federal Endangered Species Act (ESA) (H) and Kentucky Mussel Refuges pertain to direct protection of mussel habitat. With varying degrees of protection, permitting statutes (Sections 10, 404, and state 401 certification) also regulate activities that can directly benefit mussels and their habitats. The remaining actions listed in **Table 5-1** benefit mussels by potentially eliminating, reducing, and/or monitoring sources of pollution.

To a lesser extent, the Freedom of Information Act (FOIA) and enhanced environmental education, in general, should promote more responsible environmental decision-making that consequently will benefit mussels and other aquatic resources. Several other initiatives, including carbon sequestration, wetland mitigation banking, farmland preservation, effluent trading, pollution prevention, and environmental sustainability are relatively recent programs or concepts with potentially high, but unknown, benefits to mussels. These activities would need significant expansion from current funding levels to produce measurable impacts within the Ohio River corridor.

5.11 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

Native freshwater mussels are a uniquely rich component of the Ohio River's bottom fauna. Changes in current velocity and direction and resulting silt deposition associated with high-lift dams have compounded a decline in Ohio River mussels that began more than a century ago. Ohio River mussels have been resilient to invasions of Asiatic clams, but have been more severely threatened by the nonindigenous zebra mussel. Interest in protecting the remaining native mussel populations in the Ohio River is high. Coordinated monitoring and protection strategies have been undertaken and others are proposed, but the long-term outlook for native mussels is uncertain.

One of the seven environmental operating principles of the Corps is to strive to achieve ES. ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation, and maintenance to improve the quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of cumulative effects can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An Analysis of Environmental Sustainability (AES) has been and is being used in several other programmatic studies by the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps: (1) identification of "common effects" on mussels from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of indicators for ES for mussels, and their

grouping, as appropriate; and (3) consideration of the "connections" between the common effects and the indicator groups. The output of the AES consists of a qualitative (descriptive) discussion of the "connections," with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions – what is the current ES for mussels, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable – the composite conditions for the selected indicators of ES for mussels do not reflect conditions that would sustain diverse, healthy populations of freshwater mussels in the Ohio River.

- Marginally sustainable – the composite conditions for the selected indicators of ES for mussels are such that diverse populations of freshwater mussels are occurring along some segments of the river; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of freshwater mussels for the Ohio River).

- Sustainable – the composite conditions for the selected indicators of ES for mussels are such that diverse, healthy populations of freshwater mussels are occurring along the majority of the river; further, the conditions of the indicators exceed regulatory thresholds or other pertinent measures.

Four common effects of multiple actions have been previously discussed in the section entitled "Relevant Actions Affecting Mussels"; they include actions directly contributing to habitat degradation and instability, actions indirectly contributing to habitat degradation and instability, actions affecting reproductive success and community connectivity, and actions beneficial to mussels.

Five indicators of ES were identified earlier in the section entitled "Indicators of Environmental Sustainability," and relevant information on them have been presented in the section entitled "Past to Current Baseline Conditions." Regarding their relevance for ES, the following rationale is appropriate:

- suitable habitat with stable substrates, adequate depths and currents, and connectivity to other mussel populations – these indicators are related to the physical habitat requirements associated with a sustainable mussel population; specific research studies are available to support the importance of these characteristics of the physical habitat

- adequate water quality – pollutional stresses can cause degradation of various physical, chemical, and bacteriological parameters of water quality; degraded conditions are a deterrent to a robust and sustainable mussel population

- sufficient food supplies to help ensure good growth rates and reproduction – adequate food supplies are needed to support a sustainable mussel population; degraded conditions can result from habitat impacts and instability, and other interferences associated with the life cycle of freshwater mussels

- availability of fish hosts to ensure reproductive success and maintain species diversity – as described in the earlier section on life history, the glochidia of most freshwater mussels are obligate parasites of fish, thus they must quickly attach to suitable fish species in order to metamorphose into free-living mussels; therefore, appropriate fish hosts are necessary in the life cycle of freshwater mussels

- minimal disturbance from biotic stressors, such as invasive Asian clams and zebra mussels, and from abiotic stressors, such as river traffic – biotic and abiotic disturbances disrupt the life cycle of mussels, and are a deterrent to the maintenance of a sustainable population of mussels

For the purposes of this analysis, the five indicators are grouped into three tiers for conducting the AES. The three tiers are as follows:

- first tier – "physical measures of an adequate habitat and related biotic and abiotic stressors"

  (1) suitable habitat with stable substrates, adequate depths and currents, and connectivity to other mussel populations

  (2) minimal disturbance from biotic stressors, such as invasive Asian clams and zebra mussels, and from abiotic stressors, such as river traffic

- second tier – "biological and other requirements for the life cycle of freshwater mussels"

  (1) adequate water quality

  (2) sufficient food supplies to help ensure good growth rates and reproduction

  (3) availability of fish hosts to ensure reproductive success and maintain species diversity

- third tier – "composite indicator of mussel sustainability" - sustain diverse, healthy populations of freshwater mussels (this indicator reflects the collective consideration of the five indicators in the first two tiers)

Finally, the indicators and tiers are displayed in four tables, with each table coinciding with the four groups of actions with common effects. **Tables 5-10 through 5-13** are on the following pages. **Table 5-10** relates to RFFAs that directly contribute to degradation and instability of mussel habitat, accordingly, they would cause reductions in the physical measures of adequate habitat and greater habitat disturbances due to biotic and abiotic stresses. However, as noted in the above subsection entitled "Actions Directly Contributing to Habitat Degradation and Instability," mitigation measures for several of the 13 listed RFFAs are identified, thus providing the opportunity to minimize mussel habitat degradation and instability and to minimize the decline in mussel sustainability.

Table 5-11 relates to RFFAs that indirectly contribute to the degradation and instability of mussel habitat via undesirable changes in substrates, depths and currents, and connectivity; and potential increases in biotic and abiotic stressors. However, careful examination of the 10 listed RFFAs can lead to the identification of numerous mitigation measures which could be used to minimize future declines in mussel sustainability. Implementation of such measures may require development of governmental programs or requirements and related permits and inspections.

Table 5-12 focuses on RFFAs that can affect mussel reproductive success and community connectivity. As such, the 3 listed RFFAs primarily impact biological and other requirements. For example, they may contribute to changes in water quality, disrupt food supplies, and obstruct the movement and availability of fish hosts. Mitigation measures would appear to be the most promising for movement of commercial barges, power boats, and PWCs. Better management of all forms of river traffic could help in promoting mussel sustainability.

Finally, **Table 5-13** lists 4 RFFAs that are beneficial to mussels. One relates to better management of navigation traffic, one to a federal protection law and state program, and two to enhanced education and information dissemination. These RFFAs are expected to reduce disruptions to mussel habitat, help to minimize biotic and abiotic stresses, and enhance necessary biological and other requirements. As a result, more diverse and healthy populations of freshwater mussels should occur, and ES would be promoted.

TABLE 5-10
AES Tiers for Actions Directly Contributing to Habitat Degradation and Instability

Actions Directly Contributing to Habitat Degradation and Instability	Physical Measures of an Adequate Habitat and Related Stressors	Biological and Other Requirements	Composite Indicator of Mussel Sustainability
• Channel maintenance dredging (H) • Ongoing instream sand and gravel mining (H) • Construction of lock chamber extensions (H) • Barge queuing (H) • Barge floating and storage (H) • Periodic upkeep and maintenance of locks and dams (H) • Major lock rehabilitation (H) • Continuing operation of existing locks and dams (H) • Major rehabilitation of dams (H) • Pool maintenance (H) • Port development and maintenance (H)	• Suitable Habitat Regarding Substrates, Depths and Currents, and Connectivity to Other Populations • Minimal Disturbance from Biotic and Abiotic Stressors	• Adequate Water Quality • Sufficient Food Supplies • Availability and Mobility of Fish Hosts	• Sustain Diverse, Healthy Populations of Freshwater Mussels

Actions Directly Contributing to Habitat Degradation and Instability	Physical Measures of an Adequate Habitat and Related Stressors	Biological and Other Requirements	Composite Indicator of Mussel Sustainability
• Recreational activities, especially the development and maintenance of marinas and boat launch ramps (M) • Dispersed barge traffic (H)			

TABLE 5-11
AES Tiers for Actions Indirectly Contributing to Habitat Degradation and Instability

Actions Indirectly Contributing to Habitat Degradation and Instability	Physical Measures of an Adequate Habitat and Related Stressors	Biological and Other Requirements	Composite Indicator of Mussel Sustainability
• Operation of the existing navigation system (H) • Channel modifications designed to reduce flooding (H) • Floodplain sand and gravel mining (H) and limestone aggregate mining (M) • Spills of hazardous materials (H) • Acid mine drainage (H) • Industrial activities (H) • Residential, commercial, and industrial development in the floodplain (H) • Bridge construction, redesign, or replacement (H) • Other utility, industrial, and riverbed crossings (H) • Agriculture and silviculture (H)	• Suitable Habitat Regarding Substrates, Depths and Currents, and Connectivity to Other Populations • Minimal Disturbance from Biotic and Abiotic Stressors	• Adequate Water Quality • Sufficient Food Supplies • Availability and Mobility of Fish Hosts	• Sustain Diverse, Healthy Populations of Freshwater Mussels

TABLE 5-12.
AES Tiers for Actions Affecting Reproductive Success and Community Connectivity

Actions Affecting Reproductive Success and Community Connectivity	Physical Measures of an Adequate Habitat and Related Stressors	Biological and Other Requirements	Composite Indicator of Mussel Sustainability
• Impoundments (H) • Movement of commercial barges, power boats, and PWCs (H to M) • Dams obstructing the movement of fish hosts (H)	• Suitable Habitat Regarding Substrates, Depths and Currents, and Connectivity to Other Populations • Minimal Disturbance from Biotic and Abiotic Stressors	• Adequate Water Quality • Sufficient Food Supplies • Availability and Mobility of Fish Hosts	• Sustain Diverse, Healthy Populations of Freshwater Mussels

TABLE 5-13
AES Tiers for Actions Beneficial to Mussels

Actions Beneficial to Mussels	Physical Measures of an Adequate Habitat and Related Stressors	Biological and Other Requirements	Composite Indicator of Mussel Sustainability
• Nonstructural navigation improvements (H) • Endangered Species Act and Kentucky Mussel Refuges (H) • Freedom of Information Act (FOIA) (H) • Enhanced environmental education (H)	• Suitable Habitat Regarding Substrates, Depths and Currents, and Connectivity to Other Populations • Minimal Disturbance from Biotic and Abiotic Stressors	• Adequate Water Quality • Sufficient Food Supplies • Availability and Mobility of Fish Hosts	• Sustain Diverse, Healthy Populations of Freshwater Mussels

5.12 SUMMARY AND CONCLUSIONS

The cumulative effects on Ohio River native mussels from past, present, and reasonably foreseeable future actions have been addressed herein. Mussels are the river's natural filter system, and they play an important role in the breakdown/compartmentalization of organic matter as well as provide habitat for other invertebrates. They also help stabilize the substrate. Freshwater mussels feed on organic particles, algae, and minute plants and animals, thus they are important biological components in aquatic ecosystems. Not only are mussels valued ecologically, but they also serve as indicators of the quality and overall health of the aquatic ecosystem. This indicator role is facilitated by their sensitivity to stress, limited mobility, and long life span. Some species also have value as a commercial resource in the cultured pearl industry, and serve as a major component of freshwater biodiversity.

Mussels are highly dependent on other VECs during their life cycle. Proper flow regimes are essential for sustaining healthy and diverse mussel communities. The reproductive cycle of mussels is stimulated by changes in water temperature. The glochidia of most species are obligate parasites of fish and must be attached to their fish hosts within 24 to 48 hours of their release. Further, influences on benthic substrates that may result from floodplain/riparian sources can also influence the sustainability of mussel populations. Introduction and proliferation of nonindigenous zebra mussels and other invasive species is a primary concern in considering the future well being of native mussels.

The greatest factor affecting mussels in the mainstem Ohio River is habitat alteration resulting from impoundment by the high lift dams. Maintenance of the navigation pools creates year round slackwater habitat which has had and continues to have the most significant adverse effect on mussel resources. Much of the impounded habitat is no longer suitable for a diverse and healthy mussel community, nor will it become suitable in the foreseeable future. However, this is not to imply that nothing can be done within the context of this highly modified system to improve sustainability of mussel resources. The overall challenge is determining how to manage the remaining suitable riverine habitat to maintain it and optimize its utilization by mussels, while continuing to develop and evaluate a variety of methods that could be applied to expand suitable habitat and to encourage recolonization by mussels. Further, a basic concern related to the sustainability of native mussel populations in the mainstem is associated with life cycle disruptions from changes in fish movement patterns due to the navigation system and disturbances to mussel beds and bottom habitats from sediments and chemical pollution, barge traffic, and recreational boating in specific areas.

5.12.1 Describing the Affected Environment

In the latter part of the 1800s, when the Ohio River was still free flowing, upwards of 80 species of native freshwater mussels were reported for the mainstem. However in the late 1800s, declines in mussels began to occur, with contributing factors including direct habitat disturbances and indirect effects from siltation (turbidity) and organic and inorganic pollution. The lower portion of the river was not as severely affected by water quality degradation as the upper river. As a result, the lower river typically had and continues to support more diverse mussel populations and generally higher densities than the upper river. Commercial harvesting of freshwater mussels for button manufacturing, from the late nineteenth to the mid-twentieth century, also contributed to declines in the resource, as did mussel harvesting for the cultured pearl industry from the 1950s to the late 1980s. As noted earlier, in addition to directly eliminating much of the habitat suitable for mussels, the system of high-lift locks and dams also contributed to disruptions in the life cycle of the mussels by interfering with fish aided dispersion of mussels.

Concern continues to exist about the impacts of nonindigenous species such as zebra mussels and the latest indication that the black carp has been recorded in the Ohio River. It is not at all clear that levels and impacts of zebra mussels have stabilized to the point that native mussels' sustainability is possible. It should be noted there are still many uncertainties as to the life cycle requirements of freshwater mussels, the long-term effects of invasive species including zebra mussels and black carp, the specific effectiveness of

conceptually sound mitigation measures, and the ability of mussels to colonize more areas or habitat than those currently available.

Six previously designated endangered species have not been recently found in the mainstem; however, five others have been recorded fairly recently in the mainstem (mainly as very old individuals or single individuals). This trend of apparent loss and/or diminishment of listed mussel species does not bode well for sustainability of mussels in the future. In addition to already listed species, three other mussel species (spectacle case, rayed bean, and sheepnose) are currently candidate species in line to be added to this list. The spectacle case is already generally considered extirpated from the mainstem. Further, the rabbitsfoot mussel has undergone a status review and is currently being evaluated for candidate species status.

5.12.2 Assessing the Cumulative Effects of Past, Present, and Future Actions

Multiple past and present actions have affected the freshwater mussel resource of the mainstem, and multiple future actions are also anticipated to contribute to the overall CEs on mussels. The systematic evaluation of 87 types of RFFAs indicated that 56 were ranked as having "high importance" relative to CEs, and 14 were designated as having "medium importance." The fact that 70 of the 87 RFFAs were ranked as having high or medium importance is a reflection of several issues, including the large numbers of mussel beds spatially distributed in the mainstem, the interactions of mussels with other components of the aquatic and riparian environment (i.e., being sessile, nearly everything in the water and coming off the land affects mussels), the current precariousness of the mussel resource, the fairly low level of knowledge about mussels and their life cycle requirements and fragility, and the necessity for implementing a variety of resource protection measures.

Actions that physically alter mussel beds and individual mussels include channel maintenance dredging, in-stream sand and gravel mining, construction of lock chamber extensions, barge queuing or barge fleeting and storage in the vicinity of mussel beds, periodic upkeep and maintenance of lock and dam facilities, major lock or dam rehabilitation projects, port development and maintenance, recreational boat marinas and launch ramps, and barge traffic outside of designated shipping lanes (dispersed traffic).

Actions that indirectly contribute to habitat degradation or instability include those that alter water depths and velocities, composition of bottom substrates at specific locations, and/or the physical, chemical, or biological parameters of water quality. A major contributor in this category is the impoundment that resulted from construction of the high lift dams on the system. Other examples include tributary channel modifications designed to reduce flooding, increased barge traffic close to mussel beds, nearby floodplain sand and gravel mining and limestone aggregate mining, spills of hazardous materials, acid mine drainage, wastewater discharges from various municipalities and industries, floodplain development activities (residential, commercial, and industrial), bridge projects and various riverbed crossings, and stormwater runoff from urban, agricultural, and silvicultural areas. Barge traffic, recreational boats, and personal watercraft are in this category because their underwater surfaces provide attachment sites for zebra mussels.

Actions that inhibit or prevent normal mussel reproductive cycles, or actions that cause isolation of mussel bed communities were classified as affecting reproductive success and community connectivity. Impoundment of the Ohio River via high-lift locks and dams has isolated previously connected beds and affected movements of both mussels and fish hosts.

Actions beneficial to mussels include navigation traffic management via the use of nonstructural and structural measures to reduce queuing in tailwaters; continued implementation of regulatory programs such as NPDES permits for municipal and industrial point sources, along with Phase 1 and 2 programs for stormwater runoff; pollution prevention efforts; locational sensitivity associated with the Section 10 and 404 regulatory permit programs; and implementation of the requirements of the Endangered Species Act and various state laws and programs encompassing protection of mussels. While these actions collectively will not reverse the habitat loss that has occurred, they should be of some help in recolonization and restoration of mussel populations in the remaining suitable habitat.

ES has been used as the "ultimate test" whereby the significance of CEs from multiple past, present, and future actions on mussels can be qualitatively evaluated. The Analysis of ES (AES) involved "connecting" the four common effects from the 70 high and medium importance RFFAs to the five indicators of ES used to describe the historical situation, trends, and current conditions of the mussel resource. For purposes of this analysis, the indicators were divided into three tiers: 1) physical measures of adequate habitat and related biotic and abiotic stressors, 2) biological and other requirements for the life cycle of freshwater mussels, and 3) composite indicators of mussel sustainability

After the connections were determined, the conditions for the composite indicator were evaluated based on three categories of ES defined as follows:

- Not sustainable – the composite conditions for the selected indicators of ES for mussels do not reflect conditions that would sustain diverse, healthy populations of freshwater mussels in the Ohio River.

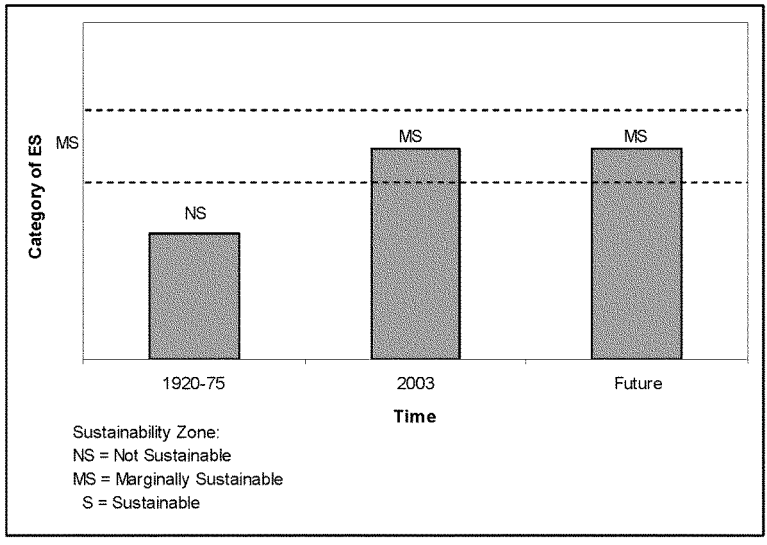
- Marginally sustainable – the composite conditions for the selected indicators of ES for mussels are such that diverse populations of freshwater mussels are occurring along some segments of the river; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of freshwater mussels for the Ohio River).

- Sustainable – the composite conditions for the selected indicators of ES for mussels are such that diverse, healthy populations of freshwater mussels are occurring along the majority of the river; further, the conditions of the indicators exceed regulatory thresholds or other pertinent measures.

Based upon the above-described conditions of the affected environment, the consideration of multiple actions and their effects, the discussion of the connections with the three tiers of indicators, and the ES categories, the ES of mussels of the mainstem of the Ohio River can be characterized and depicted in Figure 3 as follows:

In the time period from 1920, and continuing up to the mid-point of the last half of the 20th century, the ES of freshwater mussels in the mainstem was classified as "not sustainable." Analysis of the scientific data indicated substantial declines in various mussel populations in the mainstem, along with the recognition of multiple actions and factors causing such declines. Further, it was concluded that the composite conditions for the selected indicators of ES for mussels did not reflect conditions that would sustain diverse, healthy populations of freshwater mussels throughout the river.

FIGURE 5-3
ES of Freshwater Mussels



In the time period from 1975 up to 2003, some improvements in sustainability of the mussel resource in the mainstem were noted, although improvements were typically localized and exhibited frequent fluctuations. Improvements that have occurred resulted from: 1) reduced acid mine drainage in the upper river, 2) enhanced treatment requirements for municipal and industrial wastewater treatment plant discharges, 3) consideration of mussel bed locations in river-related permitting programs (e.g., Section 404 and Section 10 permits) and navigation system operational features (location of queuing and barge fleeting/storage areas and placement of dredged material), and 4) protection provided through designation of several mussel species as threatened or endangered under the ESA and similar state protective mechanisms.

Conversely, there has also been a general reduction in number of mussel beds since about 1975. Concern continues to exist about the impacts of nonindigenous species such as zebra mussels and black carp. It is not at all clear that levels and impacts of zebra mussels have stabilized to the point that native mussel sustainability is possible. Further, barge traffic is a primary vector for dispersion and continued re-infestation of zebra mussels. It should be noted there are still many uncertainties as to the life cycle requirements of freshwater mussels, the long-term effects of invasive species including zebra mussels and black carp, the specific effectiveness

of conceptually sound mitigation measures, and the ability of mussels to colonize more areas or habitat than what is currently available.

Recent fish movement research indicates evidence of some inter-pool movement (see fish resources chapter); however, it is not clear if sufficient host fish are able to move successfully from a mussel assemblage in one pool to another mussel assemblage in another pool, particularly during seasons when host fish could be expected to be carrying mussel glochidia.

Six previously designated endangered species have not been recently found in the Mainstem. However, five others continue to exist in the river, but it is not evident that these are in the recovery phase.

Based on the above, it is concluded that the current ES classification for the mussel resource is "marginally sustainable." This "marginally sustainable" classification is appropriate since the composite conditions for the selected ES indicators are such that diverse mussel populations are occurring only along some segments and in some pools of the river and that the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrence, with the conditions reflecting a continuing level of uncertainty regarding appropriate quantitative measures of the ES of freshwater mussels.

Examination of past and present conditions and an examination of the 70 RFFAs of high and medium importance to freshwater mussels resulted in the conclusion that future sustainability of mussels in the mainstem will continue to be marginal. This assessment of future marginal sustainability acknowledges that many unknowns remain and that recovery of Ohio River mainstem native mussel populations will be a long-term process involving many years of collaborative efforts and monitoring. A primary concern is that loss of mussel habitat is and will continue to be a limiting factor influencing the long-term sustainability of mussels. Development, especially river based, if not carefully planned could cause mussel resources to become unsustainable in the future. Evidence of recruitment and population stability is necessary to validate viability of mussel resources. To illustrate the many uncertainties, the following tasks to effect recovery have been selected from a more extensive list from Watters (1994) and supplemented by the ORMSS Interagency Working Group:

- Identify other resource values associated with mussel populations, including fish hosts, key food organisms, and habitat elements.
- Protect and manage mussel populations and their habitat on a site-specific basis to avoid future net loss of available habitat or populations.
- Characterize the habitat that best supports species of concern, including historically important sites.
- Restore habitats and reintroduce mussel species to suitable areas.
- Conduct searches for additional populations.
- Enforce all laws and regulations pertaining to collection of specimens and protection of habitat.
- Enhance knowledge of life histories for species of concern, including life histories of host fishes.
- Identify the potential effects and responses to zebra mussel and Asian carp invasions and their control measures.
- Evaluate the efficacy of removing zebra mussels from vessels to prevent re-infesting areas.
- Increase public and agency awareness of existing laws that protect mussels.
- Use media opportunities to reach the general public and encourage involvement in the recovery process.
- Restore and protect direct connections to tributary populations.

- Restore mobility of fish hosts through dams at appropriate times of the year needed for mussel reproduction.

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Chapter 6
RIPARIAN/FLOODPLAIN RESOURCES

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6.2 DEFINITION AND IMPORTANCE OF RIPARIAN/FLOODPLAIN TERRESTRIAL RESOURCES

This chapter considers how Cumulative Effects (CE) of human use of the Ohio River and other factors have influenced Riparian/Floodplain Resources (RFR) and what impacts to these resources may be anticipated in the foreseeable future. In the Ohio River Mainstem Systems Study (ORMSS), RFR include terrestrial habitats, wetlands, soils and geology, islands, and floodplain hydrology.

The National Research Council (NRC) (2002) has identified the lack of a consistent definition for "riparian" as a major problem of federal and state programs that might manage and protect riparian areas. To address that concern, the NRC has developed the following working definition:

> Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients of biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface

> hydrology connect water-bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines (NRC 2002).

Further, riparian areas include portions of the channel system and associated features (gravel bars, islands, and wood debris); a vegetated zone of varying successional states influenced by floods, sediment deposition, soil-formation processes, and water availability; and a transitional zone to the uplands of the valley wall - all underlain by alluvial aquifers. Although they occupy only a small proportion of the total land base in most watersheds, riparian areas are regional hot spots for biodiversity and exhibit high rates of biological productivity in contrast to larger landscapes (NRC 2002).

The varied components of RFR add to the difficulty of precisely defining them. For example, several habitat types occur within riparian areas, including wetlands, bottomland hardwood forests, prime and other agricultural land, and transitional/upland habitats. Also included in this riparian chapter are islands, which represent a unique and limited habitat type. Concerns related to riparian habitat include loss due to development, habitat conversion and fragmentation, and changes in habitat quality due to natural occurrences and human actions.

Wetlands are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (USFWS 2001). This study considers wetlands that exist within the 500-year floodplain of the Ohio River mainstem and slackwater zones of its tributaries. Construction of dams on the Ohio River inundated many mainstem wetlands while creating conditions conducive to formation of wetlands in embayments of the tributaries. Concerns related to wetland resources include wetland loss due to conversion for agricultural use or development projects, decline in quality due to modifications on adjacent lands, inappropriate and unauthorized filling, long-term changes resulting from refuge and wildlife management programs, and fragmentation.

Agricultural and forested lands along the mainstem to some extent provide habitat for a variety of species. They also can act as important buffer areas between mainland development and the Ohio River, with buffering efficiency varying with type and extent of vegetation. The amount of undisturbed terrestrial and wetland habitat remaining is one measure of the health of riparian resources along the Ohio River.

Hydrological processes since impoundment have created a few small islands in the Ohio River. Islands in general, however, typify a dynamic and diminishing resource in the mainstem. Human disturbances and an island's unique underlying geology are among factors influencing its vulnerability or persistence.

Several physical parameters related to the Ohio River also can affect riparian resources, including flow velocity, sediment transport, fluctuating pool levels, large woody debris, and manmade modifications (jetties, pipelines, marinas, etc.). Further, complex interrelationships among the various components of riparian areas, as well as interactions between riparian areas and other Valued Environmental Components (VECs) affect the

health and sustainability of riparian resources. This chapter discusses physical parameters under the general headings of floodplain hydrology and soils and geological features.

Floodplain hydrology includes factors that influence the physical characteristics and variability of water flow within a given river system and the resulting physical and biological characteristics of the riparian zone influenced by the flow regime. Factors influencing floodplain hydrology include varying combinations of climatic, geomorphic, and hydrologic processes, for example:

- Climate heavily influences watershed vegetation communities, streamflow magnitude and timing, water temperature, and many other key watershed characteristics.
- Geomorphology refers specifically to the study of the landforms on the earth and the processes that change them over time. Fluvial geomorphology, which refers to structure and dynamics of stream and river corridors, is especially important to understanding the formation and alteration of the stream or river channel, as well as the floodplain and associated upland transitional zone.
- Finally, the hydrologic cycle is a natural, solar-driven process of evaporation, condensation, precipitation, and runoff (from *Introduction to Watershed Ecology;* http://www.epa.gov/watertrain/ecology/index.html).

Compounding the influence of natural processes are changed floodplain hydrology and characteristics resulting from development projects or other human induced changes in land use. These influences include dams and other instream developments, activities along the riverbank or within the riparian zone, and upstream activities throughout the watershed.

The floodplain hydrology resulting from the combination of natural and human influences, subsequently, affects the full spectrum of riparian features. It also significantly affects the suitability of the riparian zone for various human activities such as agriculture, recreation, transportation, housing, and commerce.

Soils and geological features of lands near the mainstem are of concern for several reasons, including the land's use/eligibility as prime farmland. Further, groundwater characteristics, including flow and quality, can be disrupted by various human activities. In addition, groundwater flow can influence the movement of contaminants from waste disposal sites to the river. Soil characteristics also can be of concern due to potential erosion and contribution to non-point source water pollution. Bank instability can occur due to fluctuating water levels, propeller "wash," and inappropriate barge "toe-ins".

6.3 OBJECTIVES AND SCOPE OF THE RIPARIAN/FLOODPLAIN ECOLOGICAL RESOURCES STUDY

6.3.1 Objectives

This chapter assesses the system-wide CEs on RFR of all likely major navigation improvements along the mainstem of the Ohio River during the planning period from 2000 to 2070. Impacts directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the Corps and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFAs. These future actions include the major navigation improvements identified in this study, other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies, actions by non-government entities, and predictions of general economic expansion and development as well as regulatory changes.

Results of the CEA will lead to further consideration of:
1) the acceptability of the impacts of the RFFAs on the affected resources
2) how the proposed navigation improvements contribute to those impacts, and
3) what constitutes a sustainable system for RFR of the Ohio River mainstem.

6.3.2 Geographic Scope

The geographic focus for RFR includes the 500-year floodplain, which encompasses an area that has a 0.2 percent annual chance of flooding. In addition to the Ohio River mainstem, the area of focus includes the 500-year floodplain of tributaries and embayments that are influenced by pool elevations of the mainstem lock and dam projects.

6.3.3 Time Frame

The established time frame for this project is 1920 to 2070. The earlier date approximates the initiation of the Corps' long-term 20th century lock and dam construction activities on the Ohio River while the latter date approximates the end of the 60-year planning horizon encompassed by ORMSS. Discussion of impacts on RFR requires consideration of conditions before 1920 in order to understand how lock and dam construction and operation have interacted with other events to influence RFR.

6.4 ISSUES FROM SCOPING

A series of 12 public scoping meetings was held during summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. A more detailed discussion of the scoping meetings is presented in Exhibits A and B of this report.

The meetings were attended by 185 persons and over 200 verbal comments were recorded from the question and answer sessions. These comments accounted for the large majority of input. Additional comments were obtained from 19 questionnaires and several letters that were submitted.

Riparian/floodplain protection was a major focus of the meetings. **Table 6-1** presents comments that directly and indirectly addressed RFR.

TABLE 6-1
Comments from Public Scoping Meetings

Direct Comments on Riparian/Floodplain Resources	Relevance to Riparian/Floodplain Resources	Total Comments
Need to consider 404 application approvals and resultant actions as direct USACE actions	Potential damage to riparian areas without Corps oversight	1
Loss of shoreline trees and river property caused by barge activity	Damage to riparian vegetation by navigation activities	7
Failure of barges to stay in designated shipping lanes	Erosion and damage to riparian habitat	2
Increased spills & accidents potentially affecting aquatic life & impairing water quality	Potential loss of riparian wildlife and habitat	1
Overall effects of navigation structures & activity on groundwater levels	Changes to hydrological connections affecting groundwater	1
Need to protect public groundwater supplies	Potential groundwater pollution from floodplain activities	1
Mouths of tributaries silted in, impairing fish habitat, limiting access & damaging property	Loss of riparian habitat and economic losses due to pool maintenance	5
Need to improve sediment & erosion control from public & private developments	Protection of riparian vegetation/habitats	1
Possible use of dredge spoils to improve riparian or island habitat or for upland filling	Creation of new wildlife habitat in riparian areas; mitigation for impacts of pool maintenance	2
Habitat damage caused by Corps' permitted sand & gravel dredging	Loss or damage to riparian habitat from materials disposal	1
Bank undercutting & failure caused by increased barge traffic & queuing & wave action	Erosion and damage to riparian habitat by navigation activities	7
Bank erosion caused by Corps controlled pool fluctuations	Bank failure and damage to riparian habitat	3
Shoreline instability threatening costly restoration projects in wildlife management areas	Economic loss and physical damage to restored riparian areas	1
Need for elevation management to prevent water levels from exceeding flood stage	Protection of riparian vegetation/habitats	1
Loss of green space & wildlife habitat with development of marina facilities	Preservation of existing riparian vegetation/habitats	5
Development of floodplains & wetlands resulting in increased runoff & habitat loss	Preservation of existing riparian vegetation/habitats	4
Need for coordination with community floodplain coordinators along river	Better riparian protection through more uniform floodplain regulations	1
Loss of wildlife corridors as shoreline develops	Preservation of existing riparian vegetation/habitats	2
Need to focus on riparian corridors & green space near power plants	Lessening of aesthetic and runoff impacts	1
Clarification of differences between floodway and floodplain	Enhanced understanding of riparian areas	1
Other Comments with Implications for Riparian/Floodplain Resources	**Relevance to Riparian/Floodplain Resources**	**Total Comments**
Importance of including commercial dredging & associated permitting process in CEA	Potential impacts of these activities on riparian areas	2
Complaints received by Ohio Division of Watercraft about barges damaging shoreline	Potential impacts of this activity on riparian areas	1

Direct Comments on Riparian/Floodplain Resources	Relevance to Riparian/Floodplain Resources	Total Comments
near Greenup L/D		
Need for long-term plan to address silt removal & prevent future sedimentation	Protection of riparian vegetation/habitats	1
Damage/destruction of mussel beds & fish spawning areas	Related to embayments that are aquatic nursery areas	4
Severe erosion occurring at Slough Wildlife Management Area near Henderson, KY	Economic loss and physical damage to restored riparian area	1
Pools maintained at higher levels than agreed on in flowage easement contracts with property owners	Protection of riparian vegetation/habitats & property	2
Loss of significant farmland to urban development along river corridor	Loss of associated wildlife areas & groundwater connections	3
Need to develop comprehensive plans for development along river	Protection of riparian vegetation/habitats	3
Danger to recreational users of submerged trees toppled by bank erosion	Safety concerns related to riparian erosion damage	1
Increased development of scenic byways & bikeways	Enhanced use and appreciation of riparian areas	2
Loss of unique, sensitive species due to water quality problems & habitat modifications	Preservation of existing riparian vegetation/habitats	2
Riverfront development constraints related to endangered species	Concern related legislation will inhibit development	1
Need for stricter litter laws	Relates to riparian area aesthetics	1

6.5 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY

Indicators of Environmental Sustainability (ES), which vary by VEC, generally provide benchmarks for measuring CEs on a given resource or VEC. The primary uses of indicators are to characterize the current status of a resource and to track or predict significant changes to the resource.

The ES indicators selected for RFR include:

- adequacy of hydrologic connections between riparian areas and
- adjacent water bodies and uplands
- capacity for water storage in floodplain
- quality of soil structures
- adequacy of water table and groundwater recharge
- sustainability of sediment dynamics
- capacity of riparian areas to intercept pollution
- integrity of riparian habitats, and
- measures of biodiversity

An important feature of the definition of riparian areas quoted at the beginning of this chapter is the concept of riparian areas having gradients in environmental conditions and functions between upland and aquatic ecosystems (NRC 2002). The eight indicators listed above were developed within the context of functionality because a resource cannot be sustainable if its functions are impaired. Environmental services performed by riparian areas generally fall into three major functional categories: 1) hydrology and sediment

dynamics, 2) biogeochemistry and nutrient cycling, and 3) habitat and food web maintenance.

The following text from NRC (2002) makes connections between riparian functions and the indicators listed above:

> Functions related to hydrology and sediment dynamics include storage of surface water and sediment, which reduces damage from floods downstream from the riparian area. Riparian areas intercept, cycle and accumulate chemical constituents in shallow subsurface flow to varying degrees, with the societal benefit of removing pollutants from overland flow and shallow groundwater that might otherwise contaminate nearby waterbodies.
>
> Maintaining biodiversity is one of the most important functions of riparian areas and is the basis for many valued fisheries, in addition to birds and other wildlife habitat. The benefits of functioning riparian areas to fish stem directly from the role of vegetation in controlling temperatures, stream structure, and sedimentation. Riparian areas themselves are home to an abundance of animal life, including invertebrates, almost all amphibian species and many reptiles, the majority of bird species (particularly in the semi-arid West) and many mammal species with semiaquatic habitats. In addition to being characterized by unique assemblages of plants compared to wetlands and uplands, riparian areas frequently harbor rare plant species.

6.6 LAWS, REGULATIONS, ORDINANCES, AND PROGRAMS

Legal strategies to manage and protect riparian areas have only begun to be developed in the past decade. Most frequently, riparian protection is an indirect consequence of other environmental objectives, such as improving water quality or protecting wetlands. **Table 6-2** illustrates the broad spectrum of federal regulations and established programs that directly or indirectly influence RFR associated with the Ohio River mainstem.

TABLE 6-2
Laws, Regulations, Ordinances and Programs Relevant to RFR

Law/Program	Key Components	Relevance to RFR
Clean Water Act (CWA) (U.S. Environmental Protection Agency)	• Establishes structure for regulating pollution discharges into U.S. waters (NPDES permits) • Gives EPA authority to implement pollution control programs • Requires establishment of water quality standards • Recognizes need to address nonpoint source pollution	Implementation plans to achieve water quality standards in impaired waterbodies can involve riparian management strategies. Specific provisions of the CWA (e.g., §319) provide for demonstration projects in riparian areas.
National Environmental Policy Act (NEPA)	• Requires preparation of environmental impact	Includes water quality & habitat impacts of new

Law/Program	Key Components	Relevance to RFR
(Council on Environmental Quality & other agencies)	assessments for new construction projects by private and governmental agencies.	projects along the Ohio River such as power plants, Corps projects and riverfront developments.
Water Resources Development Act (U.S. Army Corps of Engineers)	• Authorizes Corps' port development, navigation, flood control and erosion control projects through the 1986 act and subsequent amendments	Contains provisions for environmental assessment and mitigation
National Flood Insurance Act (Federal Emergency Management Agency)	• Encourages adoption of state & local floodplain regulations restricting certain types of development within floodplains.	Limits development impacts in riparian areas.
Safe Drinking Water Act (SDWA) (USEPA)	• Provides for establishment of primary regulations for the protection of public health and secondary regulations related to taste, odor and appearance of drinking water	Helps protect public water supplies for approximately three million people who use Ohio River as their source of drinking water
Oil Pollution Act (USEPA & U.S. Coast Guard)	• Strengthened EPA's ability to prevent & respond to catastrophic oil spills	Protects RFR from pollution & damage from oil spills.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (USEPA)	• Provides for liability, compensation, cleanup and emergency response for hazardous substances released into the environment and cleanup of inactive hazardous waste sites	Includes abandoned hazardous waste sites in the floodplain.
Emergency Wetlands Resources Act (U.S. Fish & Wildlife Service)	• Authorizes purchase of wetlands from Land and Water Conservation fund • Requires states to include wetlands in Comprehensive Outdoor Recreation Plans • Provides funding for the Migratory Bird Conservation Fund	Encourages federal-state cooperation in wetlands protection and outlines funding mechanisms
Endangered Species Act (USFWS)	• Authorizes determination & listing of threatened & endangered species • Prohibits unauthorized taking, possession, sale & transport of endangered species • Provides for land acquisition to protect endangered species	Establishes framework for protection of threatened & endangered riparian species
Fish & Wildlife Act (USFWS)	• Section 7(a) requires USDI to take steps required for management & protection of fish & wildlife resources through research, acquisition of land & water & other means.	Establishes a comprehensive national fish & wildlife policy applicable to RFR
Fish & Wildlife Coordination Act (USFWS)	• Requires that whenever water bodies are modified by federal agency, that agency first shall consult with the USFWS and with appropriate state agencies with a view toward wildlife conservation	Provides for equal consideration and coordination of RFR wildlife conservation with other aspects of water resources development

Law/Program	Key Components	Relevance to RFR
Migratory Bird Conservation Act (U.S. Dept. of Interior)	• Provides for the acquisition and maintenance of public land for habitat preservation of migratory birds	Applies to land, water and transitional areas, e.g., riparian areas
Migratory Bird Treaty Act (U.S. Dept. of Interior)	• Implements various treaties and conventions between the U.S., Canada, Mexico, Japan and the former Soviet Union for the protection of migratory birds. Prohibits taking, killing and possession.	Protects migratory birds utilizing RFR.
National Wildlife Refuge System Administration Act & National Wildlife Refuge System Improvement Act (USFWS)	• Provides guidance for management and public use of refuge system, including development of comprehensive conservation plan for each refuge	Guide management & public use of Ohio River Islands National Wildlife Refuge
North American Wetlands Conservation Act (USFWS with North American Wetlands Conservation Council)	• Provides funding and implementation of the North American Waterfowl Management Plan & North American nations wetlands agreement	Provides funding support for migratory bird conservation in the Ohio River valley
National Invasive Species Act (U.S. Dept. of Trans-portation and Aquatic Nuisance Species Task Force)	• Requires all vessels operating in US waters that are equipped with ballast tanks to comply with guidelines designed to prevent and reduce the dispersal of aquatic nuisance species	Helps reduce the further introduction and dispersal of invasive species that can disrupt riparian ecosystems
Refuge Recreation Act (U.S. Dept. of Interior)	• Authorizes USDI to administer conservation areas for recreational use when such uses do not interfere with areas' primary purpose	Allows recreational use of Ohio River Islands National Wildlife Refuge
Farm Security and Rural Investment Act of 2002 (a.k.a. Farm Bill) (USDA Natural Resources Conservation Service)	• Includes various incentive programs to promote installation of riparian buffers. • Swampbuster provisions withhold certain USDA benefits from farmers who convert or modify wetlands • Offers opportunities for wetlands mitigation	Helps improve and/or preserve environmental functions & value of riparian areas in the Ohio River floodplain
Executive Order 11988, Floodplain Management & Executive Order 11990 (Both in 1977) (Executive Branch)	• Prevents federal agencies from contributing to the adverse impacts of floodplain development & modification	Restricts federal development in Ohio River floodplain wherever there are practicable alternatives
Executive Order 13112, Invasive Species (1999) Multi-agency National Invasive Species Council)	• Requires federal agencies to prevent the introduction of invasive species and provide for their control and to minimize their economic, ecological and human health impacts.	Helps to maintain and/or restore the ecological integrity of riparian areas.

Law/Program	Key Components	Relevance to RFR
Corps Permitting Statutes (U.S. Army Corps of Engineers)	• Section 10 of Rivers and Harbors Act (1899) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. • Section 404 of Clean Water Act authorizes the Corps to issue permits for the discharge or dredged and fill materials into U.S. waters.	Permits require assessment of impacts on water quality and aquatic ecological resources and mandate mitigation of adverse impacts
Small Navigation Projects (USACE)	• Section 107 of Rivers and Harbor Act (1960) authorizes COE to develop and construct small navigation projects for harbor protection.	Includes impacts of such actions on riparian/floodplain resources
State Water Quality Certification (Appropriate state or interstate pollution control agencies)	• Section 401 of the Clean Water Act (CWA) requires certification from state or interstate water control agencies that a project is in compliance with established effluent limits and water quality standards.	Provides opportunity for state or interstate scrutiny of such actions on riparian and other aquatic resources
Site Remediation Statutes (USEPA)	• Includes CERCLA, RCRA, SARA and related state programs that focus on cleanup and restoration of contaminated sites.	Potentially reduces groundwater and soil pollution sources and contributions to pollution loads in the Ohio River
TMDL Program (USEPA)	• Increasingly important section (§303) of CWA; regulates maximum pollutant load a water body can receive and still attain water quality standards.	Many TMDL implementation plans require restoration of riparian areas as a management measure to achieve nonpoint source pollution reductions.
Phase 1 & 2 NPDES Program (USEPA)	• Also developed within the CWA, requires municipalities and certain industrial and construction sites to adopt BMPs to control nonpoint sources of pollution.	Should reduce pollution characteristics of stormwater discharges from urban and industrial zones along the Ohio River
National CSO Control Policy (USEPA)	• Published by USEPA, calls for communities to implement long-term plan for combined sewer overflows (CSOs) to comply with the CWA. •	Should reduce pollution to RFR from a major urban source
Spill Response (U.S. Coast Guard, ORSANCO)	• Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the Clean Water Act.	Minimizes adverse impacts of spills and discharges on RFR and on water quality
ORSANCO Monitoring (ORSANCO)	• Encompasses ongoing water quality and aquatic ecology monitoring programs by the Ohio River Valley Water Sanitation Commission.	Helps track trends in water quality and biological communities and provides database that can inform env.decision-making

6.7 PAST TO CURRENT BASELINE CONDITIONS

In *Riparian Areas: Functions and Strategies for Management*, the NRC underscores the profound lack of information on riparian land status and trends in the United States (NRC 2002). Before riparian functions began to be understood, the majority of riparian areas in the U.S. were converted or degraded such that their functions were greatly diminished in comparison to what occurred historically. Limited landscape level assessments indicate that the spatial extent of riparian forest has been substantially reduced, plant communities on floodplains have been converted to other land uses or replaced by developments, and the area of both woody and non-woody riparian communities has decreased. These nationwide trends are applicable to Ohio River riparian areas.

Wetland components of riparian areas have received greater attention historically and provide some information about trends in riparian acreage and condition. Four of the seven states that have experienced the greatest wetland losses nationally are in the Ohio River basin -- Ohio, Kentucky, Indiana and Illinois.

The following baseline information on the Ohio River mainstem RFR focuses on terrestrial habitats; including wetlands, and the underlying geology; soils; and floodplain hydrology which have influenced their composition and which sustain RFR. Limited information on trends in riparian areas over time is included later in this section.

6.7.1 Physiography and Geomorphic Considerations

Based on average annual discharge, the Ohio River is the second largest river in the United States, surpassed only by the Mississippi River, below its confluence with the Ohio (USGS streamflow data, cited in USEPA 2000). The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, and flows 981 miles in a southwesterly direction to join the Mississippi River at Cairo, Illinois. The elevation of the Ohio's riverbed drops 429 feet from the headwaters to its confluence with the Mississippi River (USEPA 2000). The mainstem's major tributaries, from upstream to downstream, include the Allegheny, Monongahela, Beaver, Muskingum, Kanawha, Guyandotte, Big Sandy, Scioto, Licking, Great Miami, Kentucky, Green, Wabash, Cumberland, and Tennessee rivers. The 203,940 sq.-mi. Ohio River basin encompasses several physiographic provinces, but the Ohio mainstem is primarily influenced by the four provinces described in **Table 6-3**.

TABLE 6-3
Physiographic Provinces Associated with the Ohio River Mainstem

Physical Features	Appalachian Plateau	Central Lowlands	Interior Low Plateau	Coastal Plain
Location relative to mainstem	Pittsburgh (RM 0) to Vanceburg KY (RM 380)	North of Ohio River from central Ohio through Indiana and Illinois	Vanceburg, KY (RM 380) to New Liberty, IL (RM 928)	Approx. New Liberty, IL (RM 928) to Cairo, IL (RM 981)
Topography	Moderate to strong relief Steep stream gradients	Flat to slightly rolling due to glaciation	Rolling hills underlain by limestone to lower plateaus with silt-filled valleys	Undulating plains of reconsolidated sediments and highly dissected loess capped bluffs
Floodplain	Well-developed alluvial floodplain with numerous meanders Narrow valley	Not included in Ohio River floodplain*	Floodplain flattens from upstream to downstream; very broad in places (up to 7.5 mi. wide)	Extensive floodplain with sandy ridges forming natural levees, numerous swamps, islands and sandbars Lowest 11 miles to river are composed of Mississippi River delta and its bottomlands Remnant of higher floodplains exist as terraces
Groundwater supplies	Moderate supplies in permeable sand & gravel	Extensive supplies in some areas with buried pre-glacial streams	Variability typical of limestone areas	
Soils	Poor quality	Till Plains include some of basin's richest agricultural land	Good agricultural soils to thin forested soils	Sandy; some unstable loess
*Natural features and human activities within the Central Lowlands influence the Ohio River mainstem, but do not overlap with the river. This is consistent with glaciation of the Till Plains and the role of glaciation in determining the present-day course of the Ohio River south of the glacial boundary.				
SOURCES: U.S. Army Corps of Engineers, 2000. ORMSS Integrated Decision Document and Environmental Assessment, Ohio River Ecosystem Restoration Program, Appendix C, and U.S. Fish & Wildlife Service, Ohio River Valley Ecosystem Team, 1999. Strategic Plan for Conservation of Fish and Wildlife Service Trust Resources in the Ohio River Valley Ecosystem.				

6.7.2 Floodplain Description

Thorp (1992) noted that the Ohio River has a constricted channel upstream of Louisville, Kentucky (RM606); however, small floodplains are common within portions of this area. Downstream from Louisville, Thorp describes the Ohio River as a floodplain river. While this description is generally true, the dimensions of the Ohio River floodplain in various river reaches are influenced by the erodibility of the rocks forming the valley (USACE 2000). The floodplain is narrow upstream (e.g., 0.8 mi. at Pittsburgh) as it flows

through a relatively flat-lying sequence of sedimentary rocks. By Vanceburg, KY (RM 380) the floodplain has broadened to 1.6 miles, but then remains fairly narrow almost to Louisville, because the valley walls are formed by relatively resistant shaly limestone. From above Louisville to West Point, KY (RM 630), the floodplain widens where more erodible soft shales form the valley walls. Downstream from West Point, however, the river enters an area of more resistant limestone and the valley narrows for approximately 90 miles. Near Hawesville, KY (RM 724), the valley enters soft shale and sandstone and, consequently, broadens. The valley narrows again near Shawneetown, IL (RM 858) where more resistant sandstones occur, then broadens near the confluence with the Cumberland River (RM 920), where the floodplain consists of soft unconsolidated sediments of the Mississippi Valley (USACE 2000). Land use data and National Land Cover maps for the Ohio River floodplain are included in Exhibit D, Land Use.

Although the drainage area for the Ohio River Basin totals 203,940 square miles, the drainage area encompassed by Ohio River tributaries with watersheds of 1,000 square miles or greater is 182,370 square miles, or 89.4 percent of the total drainage area (USACE 2000). Consequently, less than 11 percent of the entire Ohio River drainage basin contributes directly to the mainstem.

The *Ohio River Restoration Program Environmental Assessment* (USACE 2000) describes the Ohio mainstem as a relatively stable river when compared with other systems of similar size and type. This is verified by considering the hydraulic relations for a variety of rivers and comparing conditions that occur on the average for other alluvial river systems. The Ohio River is narrower than alluvial channels commonly studied. Also, the depth is greater and the width-depth ratio is smaller.

6.7.3 Soils and Sedimentation

Riparian soils are highly variable in structure, particle size distribution, and other factors that occur not only horizontally across a riparian area but also vertically within a soil profile. Such variability results from interactions between streamflow patterns and sediment transport in conjunction with variations in local geology, channel morphology, and streamside vegetation. Sediments deposited on floodplains undergo biogeochemical changes that over time transform flood-deposited sediment into riparian soils. Because of their high levels of nutrient and organic matter, floodplain soils are some of the most productive agricultural soils in the nation (NRC 2002).

The alluvial sediments on the upper Ohio River Valley consist of glaciofluvial fill or medium to coarse-grained sand and gravel of Wisconsin Stage and post-glacial terrace deposits mainly of the "point-bar" type of river sediment. These glaciofluvial deposits are as much as 125 feet thick and are composed of 45 to 83 percent locally derived pebbles of Pennsylvanian and Permian rock derivation, and foreign pebbles. Granite, quartzite, vein quartz, and chert pebbles comprise the foreign material that has been introduced into the watershed by glaciation. The sedimentary structures are predominately the cut and fill type that is characteristic of aggrading streams. The individual beds are highly lenticular and there are abrupt changes in particle size, both horizontally and vertically. The floodplains commonly consist of thick sections of sand, silt, and clay that are commonly referred to as loams. Eolian deposits, known as loess, occur as a blanket deposit along the Ohio River in

the Purchase and Western Coal Field regions. Away from the river, these deposits grade into loams. East of mile point 785 and the Green River, there is very little typical loess.

In the area of the Ohio River Islands National Wildlife Refuge (RM 0 - RM 437), most soils on floodplains and islands are classified as fine sandy or silt loams of the Huntington, Chagrin, and Linside series. The Huntington and Chagrin soils are very well drained while the Linside series are classified as moderately well drained and somewhat poorly drained soils. A small amount of poorly drained Melvin silt loam is located primarily on Blennerhassett and Grape Islands (USFWS 2000b).

Table 6-4 summarizes the primary soil types bordering the Ohio River, following USDA taxonomy.

TABLE 6-4
Soil Types Bordering the Ohio River

River Segment	Predominant Soil Type	Description	Water Storage Erodibility
RM 0-25	Order-Ultisols, suborder-Udalts, great group - Hapludult.	Strongly leached acid forest soils with relatively low native fertility. Found in humid temperate and tropical areas of the world, typically on older, stable landscapes. Ultisols have a subsurface horizon in which clays have accumulated, often with strong yellowish or reddish color due to the presence of Fe oxides, such as in the 'red clay' soils of the southeastern United States. Support productive forests, but are poorly suited for continuous agriculture without the use of fertilizer and lime.	High water-holding capacity Heavily weathered and erodible
RM 25-330	Inceptisols>Onchrepts> Dystrochrepts	**Inceptisols** exhibit minimal horizon development and lack features that are characteristic of more developed soil orders. They are widely distributed, occur under a wide range of ecological settings and are often found on fairly steep slopes, young geomorphic surfaces, and on resistant parent materials. Land use varies considerably. Inceptisols are often found in mountainous areas and are used for forestry, recreation, and watershed. **Dystrochrepts** soils are generally thin and weakly developed with a large percentage of rock fragments. Forest productivity is dependent on availability of water due to low water holding capacity of these soils.	Water holding capacity varies with amount of rock fragments.
RM 330-410	Alfisol>Udalf	**Alfisols** are moderately leached forest soils that have relatively high native fertility. These soils are well developed and contain a subsurface horizon in which clays have accumulated. Mostly found in temperate humid and subhumid regions of the world.	

River Segment	Predominant Soil Type	Description	Water Storage Erodibility
		The combination of generally favorable climate and high native fertility promotes very productive soils for both agricultural and silvicultural use.	
RM 410-580	Inceptisols>Onchrepts> Eutrochrepts	**Eutrochrepts** form in glacial till, have low water holding capacity due to the large percentage of rock fragments in the subsoil, and are most suitable for pasture and grazing.	
RM 580-610	Alfisol>Udalf	See above.	
RM 640-710	Order-Ultisols, suborder-Udalts	See above.	
RM 710-981	Mollisol>Aquolls	**Mollisols** form in grassland ecosystems and are characterized by a thick, dark surface horizon. This fertile surface horizon, known as a mollic epipedon, results from the long-term addition of organic materials derived from plant roots. Poorly drained Aquolls occupy lower-lying landscape positions.	Aquolls have high water-holding capacity. May require tile drainage to make crop production possible.
SOURCE: Natural Resources Conservation Service. 1999. *Soil Taxonomy, A Basic System of* Soil Classification for Making and Interpreting Soil Surveys. 2nd ed.			

6.7.4 Hydrological Considerations

In addition to precipitation, riparian areas along the Ohio River mainstem receive water from three main sources: 1) groundwater discharge, 2) overland and shallow subsurface flow from adjacent uplands, and 3) flow from the Ohio River by various pathways. General functions related to riparian hydrology include storage of water and sediment, which reduces flood damage to areas downstream. Riparian areas also intercept, cycle and accumulate chemical constituents in shallow subsurface flow, with the environmental benefit of removing pollutants from overland flow and shallow groundwater that might otherwise contaminate nearby waterbodies (NRC 2002).

Groundwater is available from three sources along the Ohio River mainstem:

1) Most groundwater along the mainstem's length is recovered by induced river discharge from the predominantly Pleistocene glacial-outwash sediments over which the Ohio River flows. These sediments, consisting of unconsolidated sand, gravel, silt, and clay deposits, can yield large volumes of water to industrial, municipal, and domestic wells. An ORSANCO groundwater publication from 1984 includes an estimate of 4,500 billion gallons of water stored in the Ohio River mainstem aquifer. Because aquifer volume increases with downstream distance, more than 70 % of the storage is in the lower river, as indicated in **Table 6-5**:

TABLE 6-5
Water Stored in the Ohio River Aquifer

River Reach	Groundwater Stored (billions of gallons	% of Total
Upper Third	371	8.2
Middle Third	875	19.4
Lower Third	3,255	72.3
Total	4,501	
SOURCE: ORSANCO 1984		

Because surface contaminants can migrate quickly through coarser sediments, the Ohio River alluvium is sensitive to pollution. In fact, the Kentucky groundwater sensitivity map depicts the Ohio River aquifer as highly sensitive to contamination (http://kgsweb.uky.edu/download/wrs/sensitivity.pdf).

2) Groundwater is also associated with the Coastal Plain at the confluence with the Mississippi River in southwestern Kentucky and extreme southern Illinois. Semi-consolidated Cretaceous-age and younger sand, silt, gravel and clay deposits underlie this area. The coarser sediments are prolific aquifers for multiple uses, but are sensitive to pollution, especially at shallow depths. In general, however, the relatively low flow velocity within deeper saturation zones provides significant protection from contamination. Consequently, the Kentucky groundwater map rates groundwater contamination sensitivity as slight to moderate.

3) Groundwater also is found in the bedrock beneath the alluvial deposits and soils along the mainstem, but has less influence on riparian areas than the alluvial sources.

Groundwater adjacent to the Ohio River contains varying amounts of calcium, magnesium, iron, and other ions that contribute to water hardness, expressed as parts per million (ppm) of dissolved solids. Salt brines, with dissolved solids concentration exceeding 1,000 ppm occur at depths of less than 150 feet below the ground surface along many parts of the Ohio (USACE 2000).

Many ecological functions along the Ohio River have been lost, as riparian areas have become hydrologically disconnected from their adjacent stream channels. Such disconnections occur, for example, when local topography and soils are altered by agricultural activities or by development and its associated infrastructure. Floodplain and instream sand and gravel mining also potentially modify riparian hydrology, influencing groundwater levels, overbank flow, bank stability, and the character of riparian vegetation. Impoundment of the river for navigation has elevated the water table and has significantly affected RFR. Deepwater habitats of navigation pools have replaced the varied habitats of islands, gravel bars, riffles, and channel wetlands, while some new habitats have been created in embayments. The CE of these and other activities on Ohio River hydrology are discussed later in this chapter (USFWS 2001).

6.7.5 Extent of Floodplain and Riparian Corridors

One method to assess the health of riparian areas is to observe or estimate trends in riparian and floodplain acreage over time. The resulting data may be less straightforward and useful than appears at first because riparian areas are difficult to assess along larger river corridors and their extent varies with water levels. Further, acreage alone does not reveal the quality of riparian areas in terms of such important indicators as biodiversity and hydrological connections. Only limited data exist on acreage of riparian areas associated with the Ohio River mainstem. As expected, measurements of riparian and floodplain

areas have varied. The Ohio River Basin Comprehensive Survey (USACE 1968) indicated that the area of Ohio River mainstem flooded during the floods of record in the upper, middle and lower river reaches totaled 1,840,803 acres. Only 11 years later, a photo analysis by the Ohio River Basin Commission (ORBC) (1978) indicated that the Ohio River floodplain encompassed 846,700 acres. Flow/flood stages at the time of the latter analysis were not indicated.

The ORBC study provided area estimates of floodplain, floodplain wetlands and embayment wetlands for the upper, middle and lower reaches of the Ohio River, as shown in **Table 6-6**.

TABLE 6-6
Area of Floodplains and Wetlands for Ohio River Mainstem

	Total River	Lower River (RM546-981)	Middle River (RM 266-546)	Upper River (RM 0-266)
Floodplain (acres)	846,700	602,100	144,700	99,900
Floodplain Wetlands	19,500 ac. (2.3% of floodplain)	18,000[1] (3.0%)	640[1] (0.4%)	860 (0.87%)
Embayment Wetlands[2]	13,500 ac.	6,000 ac.	4560	2940
[1]Much of the remaining floodplain (584,000 acres on lower river and 144,700 on middle river) was previously wetlands which have been cleared of timber and drained or filled for agriculture and other uses. [2]Represents all of embayment areas associated with navigation pool slackwater, prior to completion of Smithland Lock and Dam.				
SOURCE: ORBC 1978.				

More recently, the USWFS (2000a) analyzed aerial photos to estimate the miles of riparian habitat remaining along the Ohio River. The analysis used 1800 as a benchmark year and assumed that at that time, the entire river corridor was forested, therefore, encompassing 1,962 linear miles on both banks of the river. The length of the remaining intact riparian forested areas along each riverbank was calculated by examining aerial photographs from randomly selected 20-mile stretches of river in the Pittsburgh, Huntington and Louisville Corps' Districts. Intact riparian forested areas were defined as having stable, undeveloped banks that support mature native riparian vegetation of sufficient width to provide some habitat value and/or provide buffering from mainland development. The percent forested riparian areas for each evaluated reach was calculated and extrapolated to determine the total number of riparian habitat miles remaining, as shown in **Table 6-7**:

This analysis indicates that slightly more than 50 percent of all types of riparian habitat along the Ohio River has been lost since 1800. Additionally, disproportionate losses in the upper and middle river are consistent with historic patterns of settlement and development.

TABLE 6-7
Riparian Habitat Remaining along Ohio River Mainstem
Based on Aerial Photography Analysis

Corps District	Date of Photos	Total River Miles (Both banks)	% Riparian Habitat Remaining	Miles of Riparian Habitat Lost
Pittsburgh	1995	254.4	29	180.6
Huntington	1984	621.6	34	410.2
Louisville	1995	1086.0	62.4	408.3
TOTAL		1962.0		**999.1**
SOURCE: USACE 2000a.				

Habitat values are enhanced when long stretches of riparian corridor remain intact. Such corridors may provide connectivity between patches of upland habitat for land-based wildlife. On the Ohio River, as along other rivers, long segments of riparian corridor support annual movements of migratory birds and also supply good habitat for mammals.

6.7.6 Riparian Habitats

Many studies have indicated that the contributions of riparian areas in maintaining biodiversity far exceed the proportion of the landscape they occupy (NRC 2002). The structural diversity of riparian plant communities affords a wide variety of niches for animal species that live in riparian areas on both a short-term and long-term basis. Riparian habitat types along the Ohio mainstem overlap considerably and include wetlands, bottomland hardwood forests, riparian edge/shoreline areas, embayments, and islands.

Prior to impoundment, the Ohio River was a relatively shallow river with numerous islands, gravel bars, channel wetlands (riverine emergent and riverine aquatic bed), and adjacent overflow sloughs surrounded by bottomland hardwood forests. Impoundment of the river for navigation interests created primarily deepwater habitat along the main channel corridor (average depth in channel 20-30 feet), with many islands, shallow bars and channel wetlands consequently disappearing. Most of the remaining shallow water and wetlands in the floodplain occur in embayments – the tributary mouths inundated by backwaters from the impounded Ohio River (USFWS 2000a). Later in this chapter, Table 9 summarizes riparian habitat types in the Ohio Islands National Wildlife Refuge from the Montgomery to Meldahl pools.

6.7.7 Wetlands

Wetlands formed by rivers are of several types, including oxbow marshes, floodplain bottomlands, and backwater lakes. An oxbow pond is formed when a meandering river changes course and leaves a portion of its channel isolated except during floods. In time, this pond fills in and becomes an oxbow marsh.

Backwater (bottomland) lakes form when soil and sand settle out of river currents and form long islands in the river. If such an island becomes high enough to completely separate the side channel from the main river, a bottomland lake is formed. In addition, human activities create as well as destroy wetlands. Impoundments, excavations, and the construction of dikes produce some wetlands.

Emergent wetlands are dominated by erect, rooted, herbaceous hydrophytic vegetation (e.g.,, sedges, grasses, and numerous species of forbs). Vegetation may remain visible throughout the year or die back in the nongrowing season. Emergent wetlands are classified into two categories: shallow marsh/wet meadow (where standing water or soil saturation is present for brief to moderate periods during the growing season) and deep marsh (where standing water is present, or the soil is saturated, on a semipermanent to permanent basis during the growing season). Examples of wet meadow include sedge meadows dominated by tussock sedge (*Carex stricta*), and wet prairie dominated by cord grass (*Spartina pectinata*). Water depth in marshes ranges from zero (saturated soil) to 6.6 feet (2m). In Midwestern marshes, both floating-leaf plants (e.g., water lily, *Nymphaea tuberosa*) and submerged aquatic plants (e.g., pondweed, *Potamogeton*) are frequently associated with cattails and emergent species. The soils that underlie marshes are sometimes mineral, but are often covered by muck (organic sediment).

Marshes are highly productive habitats in which hundreds of species of birds, insects, and other wildlife spend most of their lives. Two factors account for the high productivity of marshes. One is the ability of marsh plants to capture large amounts of energy from the sun and transform and store much of it as chemical energy in the form of plant tissue. The other is the efficient recycling of nutrients already produced.

Forested wetlands are dominated by woody vegetation. They are differentiated into swamps or bottomland forest based on the duration of the presence of water. Swamps are forested areas in which the woody vegetation is 20 feet (6m) or more in height and water is present on a permanent or semipermanent basis; the woody vegetation is adapted to prolonged exposure to standing water. Forested swamps, once common in the southern Midwest, are often dominated by bald cypress and water tupelo. The soil in forested swamps may be either organic or mineral, but usually has a topmost organic layer underlain with mineral soil. Shrub swamps are similar to forested swamps except that less of the vegetation is in the form of trees. Typical plants include willows, buttonbush, swamp rose, and a few species of dogwood growing in mostly mineral soils.

6.7.8 Bottomland Hardwood Forests

In contrast to swamps, bottomland hardwood forests are temporarily or seasonally flooded areas that usually occur along streams and rivers, usually in mineral soils. They represent the natural climax community of the Ohio River floodplain. Industrial, residential, and agricultural development, draining, and construction of dams and navigation pools have eliminated much of this habitat type. In fact, between 1800 and 1970, approximately 1,235,000 acres (65%) of the Ohio mainstem's forested floodplain habitat was lost or converted to other uses (ORBC 1978). Prior to development, a typical floodplain habitat was a matrix of bottomland forest interspersed with upland habitat components as well as other wetland types, including sloughs and oxbows. The remaining riparian area is often less than a few hundred feet wide (USFWS 2000a).

High quality bottomland hardwood forests typically have four plant layers consisting of:

1) an overstory of dominant trees, including sycamore, silver maple, eastern cottonwood, pin oak, and hickories

2) a lower canopy of smaller trees including hackberry, black locust, green ash, box elder, and black walnut
3) shrubs, including spice bush, dogwoods, poison ivy, and Virginia creeper and
4) herbaceous plants.

Density and diversity of the herbaceous ground cover varies with levels of light penetration.

Bottomland forests overlap broadly with wetlands. In most cases, historical wetland complexes along the Ohio River existed within a matrix of bottomland forest. Some bottomland forests on alluvial soils are relatively well drained, and forest on floodplain terraces may be flooded only irregularly. The interspersion of aquatic habitat types makes all types of bottomland hardwood forests especially valuable for wildlife (USFWS 2001).

Diverse floodplain forests provide good habitat for fur-bearing species such as beaver and cavity nesting species such as raccoon, fox squirrel, wood duck, pileated woodpecker, and warblers. The canopy structure and insect life also support many migratory songbirds and many species of bats (discussed in more detail later in this chapter). Mature trees provide habitat for fish-eating birds such as osprey, herons, and bald eagle, while the understory provides habitat for white-footed mice, white-tailed deer, wood thrush, Carolina wren, and other species. Significant wildlife use of bottomland forest habitats and wetlands include the Indiana bat (federally endangered), bald eagle (federally threatened), copperbelly water snake (federally threatened in the northern part of its range), several state-endangered species, furbearers, waterfowl, colonial wading birds, neotropical migrant songbirds, and a variety of reptiles and amphibians. Federal species of concern are discussed in further detail later in this chapter.

Recent studies in the Upper Mississippi River system, which appear applicable to the Ohio River System, underscore that bottomland forest dynamics are more complex than meets the eye. While existing riverine forests may appear natural and pristine, some important processes that determine forest growth and survival have been altered compared to pre-settlement conditions. Changes in the natural flood pulses and rising water tables have shifted forest composition from a diversity of tree species, including mast trees (important as wildlife food) to a more monotypic forest type dominated by silver maple. Little or no understory or seedling regeneration, crucial for bird and other wildlife diversity, occurs in such altered forest settings (UMRCC 2002). However, invasive exotic species such as honeysuckle, kudzu and garlic mustard may dominate the understory. Knutson and Klaas (1998) emphasize the need to reestablish cottonwood, willow and other understory trees to ensure a continued source of future nest and roost sites. Further, management of snags and downed woody debris and woody shrubs in the understory can provide additional structural features to improve the quality of wildlife habitat (UMRCC 2002).

6.7.9 Riparian Edge/Shoreline Areas

Riparian edge/shoreline areas are physical, chemical, and biological transition zones between terrestrial habitats and open water. Such areas are important for a variety of birds, mammals, amphibians, reptiles, and fishes dependent on this limited habitat type. These organisms also live in adjacent habitats and are discussed elsewhere. Rooted aquatic

plants or macrophytes, however, represent a conspicuous group of organisms primarily found in riparian edge/shoreline areas, as well as in embayments.

Factors controlling the growth of rooted aquatic plants include current speed, water levels, light availability, and nutrient inputs. In general, the number of macrophyte species that occur in running water compared to slower-moving water is limited (Hynes 1970). Shallow water and slower currents promote growth of vascular plants and macrophytic algae in the Ohio River (Thorp 1992). In quieter waters, aquatic vegetation provides food for river wildlife and migratory waterfowl, as well as shelter for aquatic insects and young and spawning fish.

Most information on macrophytes in the Ohio River is within the context of other studies. Pearson and Krumholz (1984) remarked that rooted aquatic vegetation is rare in the Ohio River, but when present, occurs in bands 6-20 ft. wide at depths of 4-6 ft. and 15-50 ft. offshore. Gar, crappie, and catfish are among the fishes that utilize these zones.

A 1975 study of approximately 126 miles of the upper river from Pittsburgh to New Martinsville, WV, (Koryak 1978) found that conspicuous emergent vegetation is not abundant in that reach of the mainstem. Only ten areas of significant emergent plant growth were identified, generally narrow bands parallel to the river and 150 ft. or less in length. The most impressive locations were all on the upstream, back channel sides of islands. Only one species, smartweed (*Polygonum coccineum*), was found growing in dense mats in then newly created Proctor Creek embayment near New Martinsville. Koryak, however, predicted that new embayments created by high-lift dams would eventually support productive, diverse aquatic plant communities and cited a 1975 USFWS inventory of a more stabilized embayment, Indian Short Creek (RM 79) which supported 64 plant species.

Table 6-8 lists the most common emergent and submerged riverine wetland plants reported along the Ohio River by USFWS. Rooted aquatic plants have been observed to be more abundant in the river during warm months of moderate drought when light penetration and photosynthesis increase with water clarity (Morrison, personal communication.).

TABLE 6-8

Common Submerged and Emergent Plants Along the Ohio River and Backwaters (Not including trees and shrubs)

Submerged Plants	
Scientific Name	**Common Name**
Vallisneria americana	eelgrass
Najas minor	eutrophic water-nymph
Najas flexilis	naiad
Myriophyllum heterophyllum	water milfoil
Potamogeton crispus	curly pondweed
Potamogeton diversifolius	variable pondweed
Potamogeton foliosus	leafy pondweed
Elodea nuttalli	waterweed
Ceratophyllum demersum	Coontail

Emergent Plants	
Scientific Name	**Common Name**
Justicia americana	water willow
Saururus cernuus	lizard tail
Sagittaria latifolia	duck potato
Alisma subcordatum	water plantain
Peltandra virginica	arrow arum
Iris pseudacorus	yellow iris
Acorus americanus	sweet flag
Ammania coccinea	scarlet ammania
Bidens spp.	tickseeds/beggar-ticks
Verbena hastata	blue vervain
Verbena urticifolia	white vervain
Sparganium americanum	American bur reed
Cyperus spp.	sedges
Carex spp.	sedges
Scirpus spp.	bulrushes
Juncus spp.	rushes
Eleocharis spp	spikerushes
Equisetum spp.	horsetails
Leersia spp.	cutgrass and white grass
Ludwigia spp.	primrose willows
Lythrum salicaria	purple loosestrife
Mimulus spp.	monkeyflowers
Polygonum spp.	smartweeds
Typha latifolia	cattail
SOURCE: Patricia Morrison, Ohio River Valley Ecosystem Team Leader, Ohio River Islands National Wildlife Refuge, Parkersburg, WV, e-mail communication, July 19, 2002.	

6.7.10 Embayments

Most remaining shallow water and wetland habitats in the Ohio mainstem floodplain occur in the embayments – the tributary mouths inundated by backwaters from the impounded Ohio River (USFWS 2000a). According to USFWS (2000a), major wetland habitat types and dominant plant species (if present) in embayments include:

1) **riverine open water** – deep water, mudflats, and exposed cobble/gravel;

2) **riverine emergent** – water willow, American lotus, lizardtail, bullhead lily, arrowhead, horsetail, arrow arum, yellow iris; typically adjacent to rivers

3) **riverine aquatic bed** – water celery, pondweeds, milfoils, duckweed, *Elodea* sp., coontail, naiads, and similar plants that require surface water for optimal growth and reproduction

4) **palustrine open water** - deep water and mudflats, cut-off from flow

5) **palustrine emergent** – smartweeds, wild millet, cattail, sedges, rushes, sweet flag, bulrushes, wild rye, rice, cutgrass, false nettle, spike rushes, swamp milkweed, sensitive fern, swamp rose mallow, burreed, marsh purslane, monkeyflowers, vervains, spotted and pale touch-me-nots, boneset, cardinal flower, beggar-ticks, loosestrife, seedbox, bedstraw, bugleweed, water horehound, tickseed sunflowers,

black elderberry, St. Johnswort, moneywort, ditch stonecrop, primrose willow, and dodder

6) **palustrine scrub/shrub** – black willow, brookside alder, buttonbush, dogwoods, false indigo, sandbar willow, and swamp rose

7) **palustrine forested** – black willow, eastern cottonwood, sycamore, slippery elm, silver maple, American elm, river birch, green ash, pin oak, and hackberry

In summer, during the height of the growing season, the diversity of the wetland plants and habitat types in Ohio River embayments provide excellent food and cover for migratory and resident wildlife. The shallow water habitats are important feeding areas for wading birds such as great blue herons, great egrets, and black-crowned night herons, which nest in heronries nearby and feed in the embayments while raising their young. After fledging, juvenile herons concentrate in the embayments as well. Wood ducks, mallards, and Canada geese nest and raise their broods in embayments and along the mainland wetlands in summer.

Young-of-year fishes find shelter in the riverine aquatic bed and emergent wetlands. Consequently, embayments are important nursery areas for Ohio River fishes, particularly species in the sunfish family. Embayments also support an abundance of amphibians and reptiles and at least 19 mussel species.

Typically lower water levels in the embayments during fall exposes mudflats and invertebrates as well as aquatic plants that are attractive as food for migrating shorebirds, wading birds, and waterfowl. Native wildlife food plants such as smartweeds, bulrushes, wild rye, and millet begin to die back and become available to migratory birds and other wildlife. Soft mast-producing trees and shrubs dominate in the embayments (elderberry, cherry, spicebush, hackberry, grape, and dogwoods), providing abundant food for migratory landbirds en route to their southern destinations.

During winter, the emergent wetland vegetation in the embayments lies down and dies back, but submerged aquatic vegetation and rootstocks remain as important food for wintering waterfowl and muskrats. While high water and swift currents are common on the main river in winter, the embayments provide quiet resting places off the main river for fish and wildlife.

The most comprehensive assessment of embayments and wetlands along the Ohio River has occurred in the Ohio River Islands National Wildlife Refuge's planning area, which encompasses approximately 400 Ohio River miles from the Montgomery to Meldahl pools. **Table 6-9** quantifies the habitat types within more than 5,400 acres of relatively undisturbed embayments and mainland wetlands within the refuge planning areas which are affected by Ohio River backwaters and have some significance for wildlife. The USFWS plans to include some of these priority habitats in the Ohio River Islands refuge. Riverine open water represents 35.7 percent of embayment habitat while immature and mature bottomland hardwood forests together comprise 29.2 percent of the total. Agricultural lands rank fourth (8.9 percent of the total). Of the channel wetland types typical of the natural river, only riverine aquatic bed is listed and it comprises less than 1

percent of the total habitat. Riverine emergent habitat, once typical of the natural river, is not sufficiently present to be listed.

TABLE 6-9
Priority Wetland and Embayment Habitats along the Ohio River

Habitat Type	Total Acreage	% of Total
Palustrine forested	372.5	6.9
Palustrine emergent	365.3	6.7
Palustrine scrub/shrub	136.9	2.5
Palustrine open water	136.4	2.5
Riverine open water	1,931.9	35.7
Riverine unconsolidated shorelines	107.4	2.0
Riverine aquatic bed	22.6	0.4
Mature bottomland hardwood	496.4	9.2
Immature bottomland hardwood	1,038.8	20.0
Late oldfield	210.3	3.9
Early oldfield	54.7	1.0
Agricultural land	480.4	8.9
TOTALS (<100 percent due to rounding)	**5,418.9**	**99.7***
SOURCE: USFWS. 2000a. Draft Comprehensive Conservation Plan and Environmental Assessment - Ohio River Islands National Wildlife Refuge, Appendix E.		

6.7.11 Islands

With two exceptions, the islands of the Ohio River were formed by accretion of flood deposits over mostly gravel and sandbars to the height of the floodplain. The two exceptions are Eureka and Letart Islands, whose bases are composed of bedrock (USFWS 2000a). The extensive bars where islands formed are generally located along reaches where the banks of the river eroded back and the river broadened. Most of the sediment transport and deposition associated with island formation occurred toward the end of the most recent history of glaciation. Additional information on the fluvial and geomorphologic processes at work in the formation of islands is presented in the next section of this chapter.

Because there is no longer any glacial transport of the sand, gravel, cobble, and boulders which formed the islands of the Ohio River, and because of the current navigation system and the system of flood control reservoirs in the drainage basin, it is not likely that any significant future island creation will naturally occur. For the same reasons, there will be no significant natural maintenance of existing river islands. They are then irreplaceable.

Islands are most abundant along the upper and lower reaches of the Ohio River and were once more numerous than they are today. USACE aerial photographs of the Ohio River indicate a clustering pattern of distribution with islands more abundant along the upper 200 and lower 281 miles of the river than along the 500 mile-long reach between RM 200 and 700. Notably, there is only one island in the reach between RM 400 and 500 (Pearson and Krumholz 1984). Along the upper 437 miles of the river, which encompass the Ohio River Islands National Wildlife Refuge (ORINWR), there were 61 islands in the early 1900s. With the advent of industrialization, improvements for navigation, and commercial aggregate dredging, 21 of these islands were lost and apparently one (Lesage

Island) was created. Natural forces modified at least four islands: Grape and Bat Islands were "fused" through sedimentation. A palustrine wetland complex now exists within the area between these two islands. Goose Island, formerly located between RM 230 and 231, disappeared through sedimentation and a shift in the flow direction of Mill Creek. Upper Brothers Island (or French Island) at RM 157.6 may have experienced the same fate. A change in flow patterns associated with Interstate 79 bridge pier construction in the early 1970s very quickly scoured away an island at RM 9 in the back channel of Neville Island (Michael Koryak, Personal communication).

Of the 40 existing islands between Pittsburgh, PA (RM 0) and Meldahl, Ohio (RM 437), five have been heavily urbanized and/or industrialized (i.e., Brunot, Davis, Neville, Wheeling, and Browns). Boggs Island has been extensively disturbed in recent years.

Recently, the ORINWR office completed a comprehensive assessment of the number and acreages of islands lost from the Ohio River since 1900. Of 124 islands present according to 1911-1914 navigation charts, 31 islands have disappeared, including 20 from the upper river. While some islands in the lower river have increased in size since 1900, the overall acreage gain of 1,094.8 is far outweighed by the 12,001.3 acres lost. The ORINWR analysis indicates an overall loss of 43.1 percent of historic island acreage, due primarily to pool raises, construction of high-lift dams on islands, and dredging (USFWS, undated). **Table 6-10** shows the island-by-island changes occurring since the early 1900s. Islands shown in italics no longer exist.

TABLE 6-10
Ohio River Island Gains and Losses since Early 1900s

Island*	Presence	Present Acreage	Historic Acreage	River Mile	Book Mile	Loss (acres)	Gain (acres)
Brunot Island	Y	157.2	187.2	1.6	1.8	30.0	
Davis Island	Y	57.8	34.3	4.6	4.6		23.5
Neville Island	Y	1136.1	1089.5	4.9	4.9		46.6
Deadman's Island	N		12.9		13.2	12.9	
Crow Island	N		137.9		20	137.9	
Hog Island	N		105.1		20	105.1	
Montgomery Island	N		31.4		31.4	31.4	
Phillis Island	Y	25.0	118.3	35.1	34.6	93.3	
Georgetown Island	Y	9.0	104.2	37.6	37.3	95.2	
Line Island	N		76.5		40.5	76.5	
Babbs Island	Y	38.0	104.3	41.8	41.5	66.3	
Bakers Island	N		67		48.9	67.0	
Cluster Islands	Y (1OF2)	13.0	163.6	51.8	51	150.6	
Black Island	N		126.5		53.5	126.5	
Browns Island	Y	374.2	356.7	60.9	60.5		17.5
Upper Griffen Island	Y	5.0	36.7	62.9	63.1	29.7	
Lower Griffen Island	Y	2.0	above value includes	63.5	63.1		

Island*	Presence	Present Acreage	Historic Acreage	River Mile	Book Mile	Loss (acres)	Gain (acres)
			both islands				
Mingo Island	N		162.6		70.5	162.6	
Pike Island	N		67.6		83.2	67.6	
Lower Sister Island *Upper Sister Island*	Y N	10.0	142.1 above value includes both islands	85.3 85.8	84.2	131.9	
Wheeling Island	Y	389.0	483.5	89.4	89	94.5	
Boggs Island	Y	16.0	71.5	93.2	92.7	55.5	
Captina Island	Y	17.0	78.4	108.1	107.3	61.4	
Fish Creek Island	Y	60.0	134.7		112.3	74.7	
Clines Island	N		64	113.1	115.2	64.0	
Paden Island	Y	90.0	127.7	131.8	132	37.7	
Williamson	Y	133.0	208	133.9	133.4	75.0	
Witten Towhead	Y	7.0	48.8	135.5	135.4	41.8	
Crab Island	Y	2.0	7.8	138.1	138	5.8	
Wells Island	Y	48.0	124.4	138.8	138.3	76.4	
Mill Creek Island	Y	23.0	77.8	141.3	140.8	54.8	
Grandview Island	Y	8.0	93.7	142.6	142.2	85.7	
Grape (Bat) Island	Y	38.0	114.5	151.5	151.2	76.5	
Middle Island	Y	240.0	325.8	152.8	152.6	85.8	
Upper Brothers (French)	N		60	157.6	157.6	60.0	
Broadback (Middle Brother)	Y	40.0	122.2	158.4	158	82.2	
Eureka (Lower Brothers)	Y	17.0	70.2	159.7	159.1	53.2	
Willow Island	N		63.1		161.3	63.1	
Buckley, Marietta, Kerr Island	Y	160.0	235.7	168.8	169	75.7	
Muskingum Island	Y	105.0	260.3	175.2	173.8	155.3	
Vienna, Halfway, or James	Y	30.0	94.1	178.0	177.5	64.1	
Neal Island	Y	110.0	233.6	181.1	180.3	123.6	
Blennerhassett Island	Y	500.0	730.6	185.9	185.7	230.6	
Newberry Island	Y	2.0	64	194.7	193.5	62.0	
Mustapha	Y	24.0	126.8	196.6	195.7	102.8	

Island*	Presence	Present Acreage	Historic Acreage	River Mile	Book Mile	Loss (acres)	Gain (acres)
Island							
Belleville Island	N		91.5		202.7	91.5	
Buffington Island	Y	156.0	247.9	216.4	215.8	91.9	
Oldtown Towhead Island	N		95	226.0	225.7	95.0	
Goose Island	N		155	230.0	228.8	155.0	
Letart Island (2)	Y (1 of 2)	29.0	175.2	234.9		146.2	
Eight Mile Island	Y	16.0	122.6	257.7	256.5	106.6	
Six Mile Island	N		77.1		259	77.1	
Gallipolis Island	Y	5.0	75.5	268.5	267.7	70.5	
Raccoon Island	N		73.3		274	73.3	
Lesage Island	Y	25.0		289.0			25.0
Brush Creek Island	Y	18.0	171.6	387.8	385.9	153.6	
Manchester Island No. 1	Y	24.0	52.2	395.1	393.5	28.2	
Manchester Island No. 2	Y	110.0	288.1	395.2	395	178.1	
Laughery Island	Y	28.8	160	501.8	499.2	131.2	
Big Bone Island	N		130.2		514.3	130.2	
Vevay Island	N		99.6		533	99.6	
Eighteen Mile Island	Y	131.5	197	581.5	578.8	65.5	
Twelve Mile Island	Y	142.8	212.9	592.0	589.3	70.1	
Six Mile Island	Y	77.7	113.8	597.2	594.3	36.1	
Towhead/Willow Island Towhead	Y	0.0	44.6	601.8		44.6	
Shippingport Island		224.9		604.6			224.9
Rock Island (at Falls)	N		8.4			8.4	
Goose Islands (at Falls)	Y	96.3	15.4				80.9
Corn Island (at Falls)	N		3.4		604.4	3.4	
Sand Island	Y	55.0	150.9	606.7		95.9	
Upper Blue River Island	Y	12.5	146.2	660.8	657.2	133.7	
Blue River Island	Y	2.5	160.1	662.5	658.7	157.6	
Flint Island	Y	109.0	135	688.6	685.2	26.0	
Rock Island	N		2.6		715.5	2.6	
Corn Island	N		493.9	733.4	729.1	493.9	

Island*	Presence	Present Acreage	Historic Acreage	River Mile	Book Mile	Loss (acres)	Gain (acres)
Anderson Island	Y	25.0	86.8	735.0	731	61.8	
Beeler Island (Little Yellow Bank)	N		99	752.0		99.0	
Yellow Bank Island	Y	142.8	376.7	753.8	747.5	233.9	
Little Hurricane Island	Y	258.0	787	760.4	756.1	529.0	
French Island No. 1+ Ellis Island	Y	165.0	395	765.4	760	230.0	
French Island No. 2	Y	268.0	563.5	766.0	761	295.5	
Scuffletown Island	Y	47.0		775.8			47.0
Three Mile Island	Y	119.0	202.6	779.0	773.8	83.6	
Dutch Island	Y	26.3		796.8			26.3
Henderson Island	Y	203.0	361.7	805.4	800.3	158.7	
Deadmans Island	Y	103.9	344	807.4	807.7	240.1	
Carpenter Creek Island	Y	7.5		814.6			7.5
Diamond Island	Y	1372.9	1727	818.0	811.5	354.1	
Emerald Island	Y	18.7		818.0			18.7
Diamond Island Towhead	N		122.5		821.5	122.5	
Mt. Vernon Towhead	Y	71.4	366.4	827.6	826.2	295.0	
Slim Island	Y	553.7	991	832.3	828	437.3	
Towhead Island	Y	46.0	68.9	832.5	825	22.9	
Slim Island Towhead	Y	25.0	129.3	836.6	836	104.3	
Wabash Island	Y	1742.0	2022	846.5	838.7	280.0	
Wabash Island Towhead	Y	18.7		851.0			18.7
Belle Island	N		272		845.9	272.0	
Raleigh Bar Island	Y	18.8		853.5			18.8
Lower Shawneetown Bar Island	Y	79.0		857.4			79.0
Cincinnati Island	Y	99.0		860.0			99.0
Cincinnati Island Towhead	N		69.6		862	69.6	
Saline/Cywell Island	Y	5.0	474.8	866.0	856	469.8	
Sturgeon	Y	65.0	474.6	870.0	869.7	409.6	

Island*	Presence	Present Acreage	Historic Acreage	River Mile	Book Mile	Loss (acres)	Gain (acres)
Island/Battery Rocks TH							
Cave In Rock Island	Y	179.0	242.1	878.8	870	63.1	
Walkers-McKinley Island	Y	165.0	129.5	882.9			35.5
Hurricane (Plew) Island	Y	1081.0	1128.7	885.1	876	47.7	
Hurricane Island Towhead	Y	7.0		885.1			7.0
Irish Jimmie's Island	Y	3.8		894.2			3.8
Rondeau Island	Y	278.0	418.9	899.9	890.4	140.9	
Pryor Island	Y	202.0	296.7	904.7	894	94.7	
Sisters Islands	Y	206.3	428.7	906.6	897.8	222.4	
Stewarts Island	Y	467.0	323.4	913.0	902		143.6
Deen Towhead	Y	8.7	15.2	916.0	915.9	6.5	
Cumberland Island	Y	338.0	491.1	920.0	909	153.1	
Cumberland Towhead Island	Y	68.9	136.6	922.0	922	67.7	
Cuba Towhead	Y	37.5		932.5			37.5
Owens Island	Y	258.0	343.6	932.8	922.3	85.6	
Paducah Towhead	N		120.4		935.2	120.4	
Ivy Island	Y	2.3		949.6			2.3
Mound City Bar Island	Y	107.0		970.6			107.0
Cache Island	Y	274.0	249.3	971.0			24.7
Mound City Towhead Island	Y	70.1	188.1	972.0	971.9	118.0	
Total	Y= 93 N=31	14384.6	25291.3			12001.3	1094.8

* Islands listed in *italics* no longer exist.
Source: USFWS. (undated). Incremental analysis of islands and other habitats completed by the Ohio River Island National Wildlife Refuge office.

The importance of islands in the Ohio River ecosystem can hardly be overstated, nor can their apparent vulnerability. The island habitats contain natural assemblages of plants and animals that are endemic to the ecosystem. Except at islands directly downstream from locks and dams, the head of an island generally resembles a natural riffle/run habitat, which was a major habitat of the Ohio River prior to impoundment. The distribution of bottomland and riparian habitats and deep and shallow water aquatic habitats make islands extremely beneficial to fish and other wildlife. A great diversity of species (waterfowl, shore birds, wading birds, neotropical migratory land birds, furbearers, fish, and benthic

organisms, including freshwater mussels) find these areas invaluable for resting, feeding, nesting, spawning, and other life functions. The deep and shallow water habitats associated with the islands are major fish and mussel production areas of the Ohio River. A total of 193 bird species (76 of which breed there), 42 mollusk species, at least 15 species of reptiles and amphibians, 101 species of fish, 25 mammals, and 500 species of plants have been identified so far within the Ohio River Islands National Wildlife Refuge (USFWS 2000a). Though less well documented, wildlife also is abundant in two island preserves protected by Kentucky: 1) the 81-acre Six Mile Island State Nature Preserve at RM 598 near Louisville and 2) the 1,375-acre Ohio River Islands Wildlife Management Area, which includes Rondeau, Pryor, Twin Sisters and Stewart islands between RM 901 and RM 914, in the river reach bordering Livingston County, KY, and Pope County, IL.

The shallow waters of the river provide quality habitat for freshwater mussels, including at least two federally endangered species, the pink mucket and fanshell, discussed in more detail in Chapter 5, Mussels. Bald eagles, peregrine falcons, and Indiana bats also use the refuge habitats. In addition, many species of plants and animals considered endangered, rare, or of special interest in Pennsylvania, Ohio, West Virginia, and Kentucky occur within the refuge.

6.7.12 Fluvial and Geomorphologic Processes Relevant to Island Resources

Islands are formed by geologic processes that have become better understood in recent decades. Using flume experimentation and extensive field observations, Leopold et al (1964) examined fluvial processes which can contribute to the creation, maintenance, or degradation of river bars and islands. The shape of the cross-section of a river channel at any location is a function of: 1) historic and contemporary flow regimes, 2) the quantity and character of the sediment in movement through the section, and 3) the character or composition of the materials in the bed and banks of the channel. The last will usually include vegetation. Flow exerts a shear stress upon the bed and banks. An adjusted or stable form that a channel can assume is one where shear stress is balanced by the resisting stress of the bed or bank at each point. As was discussed in the previous section, with only two exceptions, the 124 historic islands of the Ohio River are depositional features formed by fluvial processes. While much of the sediment transport and deposition which formed these islands occurred towards the end of the most recent period of glaciation, these processes still continue and are relevant to the topic of island protection and management.

Stream channel reaches divided by islands and bars are referred to as braided. Braided or anatomizing channels are typically but not always associated with riffles and friable bank materials, and offer greater resistance to flow than otherwise comparable straight channels. In the formation of braided channel river islands, the growth surfaceward of a central bar tends to concentrate flow in the flanking channels, which then scour their beds or erode their banks. As the cross-section is enlarged, the water surface is lowered, and the bar emerges as an island. In a natural stream the emergent bar may be stabilized by vegetation, which prevents the island from being easily eroded and, in addition, tends to trap fine material during high flow periods. Thus the gravel base tends to become veneered with silt. Flume experiments and field observations of bars and islands in the channels of braided streams indicate that they tend to build by addition at the downstream end and also on some parts of the lateral boundaries, but not on the upstream tip.

If a reach of river possessing a single channel is compared with an otherwise similar reach where the channel is divided by a bar or island, the braided portion will have a steeper slope. The ratio of slope of divided to undivided channels was found to range from 1.4 to 2.3 in field situations and 1.3 to 1.9 in flumes. The sum of the widths of the individual branches is also greater than the width of the undivided channel, the ratio varying from 1.6 to 2.0 in field examples and 1.05 to 1.70 in flume experiments. Steeper slopes contribute to sediment transport and to bank erosion and are often associated with coarse heterogeneous materials. All of these are conditions that contribute to braiding.

Conversely, equilibrium disruption can contribute to the erosion of braided channel bars and islands. If the banks are unerodible and the channel width confined, the capacity of the reach for the transport of sediment would be increased, reducing the likelihood of deposition. In addition, any bars or islands which formed would be attacked as flow increased, since bank erosion could not take place. Thus, for the bars or islands to become stable and divert the flow, the banks must be sufficiently erodible so that they, rather than the incipient bar or island, give way as the flow is diverted around the depositional structure. Sediment transport and a low threshold of bank erosion provide the essential conditions of braiding. Rapidly fluctuating changes in stage contribute to the instability of the transport regime and to the erosion of the banks; hence, they also provide a contributory but not essential element of the braiding environment. Heterogeneity of the bed material in the same way creates irregularities in the movement of sediment and thus also may contribute to braiding.

Braiding then represents a response or adjustment among the controlling variables, which may provide an equilibrium condition over a period of time. Braiding can be considered to represent a particular combination of variables in a continuum of river shapes and patterns. Once established, the braided pattern may be maintained with only slow modification, and the braided river reach may be as close to equilibrium as are meanders or other patterns.

Among the primary lessons applicable to the Ohio River island loss problem that can be derived from this cursory review of basic fluviology is that the islands themselves are not the basic habitat or management unit, rather the focus is the dynamic equilibrium of the larger braided channel reaches of the river. Activities such as bank stabilization or encroachment along a channel braid would be expected to create resistance and direct the attack of erosive forces elsewhere, such as at unprotected islands and bars. Similarly, moderation of stage fluctuations and scouring flood flows or sediment starvation are forces that over time would be expected to degrade island habitat. It is a serious dilemma that these activities are universally considered to be desirable "improvements" to the river, but that their long-term cumulative impacts are not conducive to maintenance of highly valued island habitat.

Fluvial processes must be carefully considered in future efforts to protect and restore Ohio River island habitat. Among the restoration opportunities available might be excavation and restoration of the filled backchannels of Crab Island at RM138.1 and French (or Upper Brothers Island) at RM157.6. Dredge spoils might be creatively disposed of at towheads where deposition is already occurring and it appears that conditions for island creation are highly favorable. Tributary depositional bars might be managed to create shoal and island habitat. Rather than or in addition to using riprap as

shoreline protection at the heads of islands, the larger issue of braided channel unit equilibrium might be considered, and islands might be protected by means of cross-sectional enlargement.

6.7.13 Upland and Unique Habitats

Historically, the Ohio River floodplain was primarily forested habitat, with scattered prairies, canebrakes, and wetlands in the floodplains of the main river and its tributaries. Scattered remnant unique habitats such as dry forest glades, post oak flatwoods, and clay barrens may still be found. Bluffs bordering some areas of the Ohio River shoreline provide habitat for a number of species of concern. Most of this area has been settled, cleared, drained, farmed, and developed, resulting in the outright loss of habitat, and fragmentation of that which remains. Significant wildlife use of upland forests in the study area includes the endangered Indiana bat and gray bat, raptors (including nesting bald eagles) and neotropical migrant songbirds, as described in the following section.

Upland habitats along the Ohio River's 981-mile expanse are varied topographically, geologically, and climatically, as reflected by the diverse flora and fauna of the river's riparian areas. For much of its course, the Ohio mainstem flows through eastern temperate forests, but as the river reaches its confluence with the Mississippi River, it flows through forests more typical of southeastern humid regions that include bald cypress and tupelo trees.

Included among the unique upland geological features visible from the Ohio River mainstem are:

- Split Rock – a large glacial conglomerate deposited during the Illinoian glaciation at present day RM 500 in Boone County, Kentucky, and
- Cave-in-Rock – a 55 ft.-wide limestone cave, now the centerpiece of Cave-in-Rock State Park at RM 881 in Hardin County, Illinois.

6.7.14 Wildlife of Ohio River Riparian Areas

As previously emphasized, the varied riparian habitats along the Ohio River support a diverse assemblage of wildlife. Birds are an especially important component of wildlife along the river and are conspicuous by their numbers, visibility, and overall species diversity. Riparian areas' diversity in plant species and variations in vertical and horizontal structure provide an array of niches for birds. Riparian areas along the Ohio River mainstem afford important habitat for breeding birds, stopover habitat for migratory birds, and wintering habitat for birds that live in North America year-round. The Ohio River corridor is poised on the boundary between the Atlantic and Pacific Flyways, and is a major migration route for birds. On the Ohio River Islands refuge, the principal species of management concern include migratory birds and endangered species.

Over 25 species of waterfowl (ducks, geese, swans, and mergansers) utilize the Ohio River corridor. The majority of these species are migratory, using riparian habitats as feeding and nesting areas. Annual floods create areas attractive to migratory waterfowl. Bottomland hardwoods produce mast (fruits and nuts), used extensively as a food source by mallards, black ducks, and wood ducks when the bottoms are flooded. More open

sloughs produce emergent vegetation used by widgeon, gadwall, blue-winged and green-winged teal, and ring-necked ducks. These wetlands also offer abundant invertebrates, an important source of protein for migrating ducks. Because the lower Ohio River is included in the Mississippi flyway, it is an important migratory route with significant wintering populations of ducks. It also is part of the wintering area for the Mississippi Valley population of the Canada goose (USFWS 2000a).

Numerous shorebirds (e.g., lesser and greater yellowlegs, spotted sandpipers, semipalmated plovers, ruddy turnstone, common snipe, American woodcock, solitary sandpiper, least sandpiper, semipalmated sandpiper and killdeer) utilize the Ohio River corridor during spring and fall migration. Important areas include mudflats and emergent wetlands. The USFWS (2000) notes that before the Ohio River was extensively altered, its floodplains and tributaries provided numerous sandbars, mudflats, and oxbows that were ideal habitat for shorebirds.

According to the Shorebird Conservation Plan for the Upper Mississippi Valley/Great Lakes Region, the Central Hardwoods Bird Conservation Region, which includes the lower Ohio River, is used by 20 shorebird species. Most are long-distance migrants that require suitable wetlands where they can replenish their fat reserves. Such staging areas must have shallow water (< 8 in. deep), and/or mudflats with sparse vegetation (<25% cover), undisturbed resting areas and abundant invertebrate food resources (http://www.manomet.org/USSCP/files.htm). Wetland conditions and use by shorebirds in inland regions are directly influenced by precipitation patterns. Consequently, the dynamics of climatic cycles and changing availability of habitat cause shorebirds migrating through the Ohio River basin to be scattered over larger areas in small numbers at numerous sites, compared to large concentrations at few major sites, as is common along the Atlantic and Pacific coasts (Skagen and Knopf 1993, Skagen et al. 1999, as cited by USFWS 2000a).

The great blue heron and green-backed herons are the most commonly observed wading birds along the Ohio River. Both species feed and roost in shallow water zones, fringe wetlands, and interior wetlands along the river and islands. Wading birds also include the interior least tern, listed as federally endangered due to low numbers and loss and degradation of nesting islands. Nesting habitat loss along many interior river systems within the population's range has occurred primarily from various channelization and irrigation projects and from construction of reservoirs and pools. The Corps, USFWS and state resource agencies currently are working together to use dredged materials to create least tern nesting habitat in Ohio River waters in Illinois. Information on the interior least tern and other federally listed species is included in **Table 6-11** at the end of this section.

The bald eagle is another federally listed species occurring in the Ohio River corridor, although in 1995 it was downlisted from an endangered to a threatened species. The USFWS (2000) indicates bald eagles are more abundant along the Ohio River in winter than at other times of the year, as they shift south from frozen lakes and rivers in the north.

Neotropical migratory landbirds (including warblers, thrushes, vireos, cuckoos, flycatchers, and tanagers) spend winters in Central or South America, but migrate to breeding grounds in the Ohio River Valley and to points north. The USFWS lists more

than 30 neotropical migrants that occur in the Ohio River watershed as species of concern. Stresses on these species include fragmentation and loss of habitat on both their wintering grounds and their spring and summer ranges (USFWS 2000a). Further information on the status and conservation of land birds along the Ohio mainstem is included in the Partners in Flight Bird Conservation Plans prepared for the Ohio Hills and Interior Low Plateaus at www.partnersinflight.org. Of 20 species of concern identified by the West Virginia Partners in Flight team, 15 species are known to nest on the Ohio River Islands National Wildlife Refuge.

More than 25 mammal species occur along the Ohio River mainstem, including furbearers such as mink, beaver, and muskrat. These species are noticeably more abundant along back channels and wetland habitats of embayments than along the main channel/navigation sides of islands (USFWS 2000a). Somewhat less conspicuous are the endangered Indiana bat and gray bat that roost along the river during summer.

Although not as conspicuous as birds or mammals, most amphibians and many reptiles are intimately associated with riparian areas and their waterbodies. Many species of amphibians and reptiles are found in Ohio River riparian zones, although most have not been well studied. However, the 15 species of reptiles and amphibians documented as of 2000 for the Ohio River Islands National Wildlife Refuge (USFWS 2000a) might be considered to be representative of the typical herpetofauna common to the Ohio River riparian zone.

The wetland habitats on and around the islands and within the embayments and mainland wetlands provide suitable habitat for and have been observed to support American toad, Fowlers toad, green frog, bullfrog, gray tree frog complex, northern spring peeper, pickerel frog, and northern leopard frog. Four species of turtles have been recorded on the refuge so far: the terrestrial eastern box turtle, and the more aquatic snapping, midland painted, and eastern spiny softshell turtles. Snakes in general are not abundant on the islands, primarily because of the tendency of the islands to flood regularly. Snakes, which might den or overwinter on the islands, would probably not survive a winter flood event. However, the occasional garter snake or black rat snake is observed on the refuge, northern water snakes swim to and from the islands. No salamander information is available.

The only Federally endangered, threatened, proposed, or candidate species of reptile or amphibian listed in the USFWS's Ohio River Valley Ecosystem Team website for counties contiguous with the Ohio River mainstem is the copperbelly water snake (*Nerodia erythrogaster neglecta*), found in several counties in Southern Illinois. In Indiana and Ohio the copperbelly water snake is threatened in the northern part of its range, but is not listed in these states in the southern part of its range near the Ohio River. However, Conservation Agreements have been signed between USFWS and the Illinois, Indiana, and Kentucky Departments of Natural Resources, other state agencies, and a number of coal companies as a means of protecting and enhancing habitat for the copperbelly in the southern portion of its range.

Amphibians and reptiles as a group are in decline. A species of concern in this group in the Ohio River is the eastern hellbender (*Cryptobranchus alleganiensis*). Lang (1968) reported that *Cryptobranchus* bones have been excavated in quantities from Indian

middens along the Ohio River, and that the hellbender was once abundant in the river and was extensively utilized as a food resource by Woodland tribes. McCoy (1982) reports that the hellbender has been extirpated from the Upper Ohio River by past acid mine drainage and industrial pollution. Similarly, the midland smooth softshell turtle (*Trionyx muticus muticus*) has apparently been extirpated from the northeastern portion of its range in major rivers of the Upper Ohio River drainage basin. McCoy states that no records of the midland smooth softshell in Pennsylvania exist after 1901 and that the character of the large rivers of the Upper Ohio drainage basin has been so altered by pollution that *T. muticus* may have been extirpated from these streams. The only well documented and relatively recent record for this turtle in West Virginia was from Mason County in 1968 (Green and Pauly, 1987).

TABLE 6-11
Reptiles, Birds and Mammals of Concern along Ohio River Mainstem

Common Name (Scientific Name)	Federal Status	Range/Habitat along Ohio River	Reasons for Concern
Reptiles			
Copperbelly water snake (*Nerodia erythrogaster neglecta*)	T (in N part of range, but not on Ohio mainstem)	Southern Indiana, southern Illinois and western Kentucky	1) Drainage and filling of lowland swamps and clearing of adjacent upland woods where they forage and hibernate. 2) Collection because of rarity, size, color and value in pet trade. 3) Predation when migration routes are interrupted by cleared areas. 4) Road kills and other human-induced mortality.
Birds			
Least tern, interior population (*Sterna antillarum*)	E	Breeds in isolated areas along Ohio River and other large inland rivers late April-August. Probably winters in coastal areas of Central and South America.	1) Loss of nesting sites on sandbars near rivers and along shorelines resulting from dams, reservoirs and other changes to river systems. 2) Nest disturbance during recreational activities, causing terns to abandon nests.
Bald eagle *(Haliaeetus leucocephalus)*	T	Range includes entire Ohio River mainstem. Generally more common during winter months. Builds huge nests in tops of trees near rivers, lake and marshes.	Upgraded from endangered to threatened status after more than three decades of conservation efforts. Continuing concerns include: 1) Hunting for feathers and talons. 2) Electrocution on power poles. 3) Poisoning from lead shot.

Common Name (Scientific Name)	Federal Status	Range/Habitat along Ohio River	Reasons for Concern
Peregrine falcon (*Falco peregrinus*)	Removed from Federal T/E list in 1999.	Migrates through Ohio River Valley in fall and spring.	Killing and illegal possession are among remaining concerns. In 1999, the USFWS began a 13-year monitoring program to obtain data that reflect the status of at least two generations of peregrines. If the species is not maintaining its recovered status, it could be re-listed.
Mammals			
Gray bat (*Myotis grisensens*)	E	Occupies limestone karst areas of Kentucky, southern Indiana and southern Illinois. During winter, gray bats hibernate in deep, vertical caves, but in summer, they roost in caves scattered along rivers.	1) Human disturbance of hibernation caves. 2) Cave commercialization and gates on caves that prevent access or alter habitat conditions 3) Habitat loss by flooding of caves.
Indiana bat (*Myotis sodalis*)	E	Found over most of eastern half of U.S. with large populations hibernating in caves in IN, IL, KY, OH and WV. In summer, they usually roost under loose tree bark (e.g., shagbark hickory).	1) Human disturbance of hibernation caves. 2) Cave commercialization and gates on caves that prevent access or alter habitat conditions 3) Loss and fragmentation of forest habitat. 4) Pesticides that contaminate bat food supply (insects), water and feeding areas.
SOURCES: USFWS endangered species website (http://midwest.fws.gov/endangered) and Ohio River Valley Ecosystem Team website (http://orve.fws.gov/endspec.html).			

Healthy, functional riparian areas also support an abundance and diversity of fish. Over 100 fish species have been recorded in the ORINWR (USFWS 2000a). Studies cited in NRC (2002) note that floodplains, side channels, and alcoves serve as low-velocity refuges during winter and during floods and provide access to abundant food resources for fish communities during flooding.

6.7.15 Invasive Exotic Plants

A summary of current RFR baseline conditions would be incomplete without discussing invasive exotic plant species, which have become an extremely serious problem along the Ohio River floodplain. In fact, the USFWS considers invasive exotic plants second only to direct habitat losses as a threat to native species (USFWS 2000a, and Morrison, personal communication). Along the RM 0 to 437 river reach considered within the scope of the Ohio River Islands National Wildlife Refuge's management strategy, one of the greatest obstacles to efforts to restore and protect wildlife habitat is invasion by non-native plants such as Japanese knotweed, mile-a-minute, and multiflora rose. The riparian corridor along this reach of the Ohio River includes a diverse assemblage of about 500

species of plants. Of these, 39 species are considered rare, 100 species are considered exotic, and 35 species are problematic invasive exotic species.

Executive Order 13112 **(Table 6-2)** defines an invasive species as a species that is: 1) non-native or alien to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. **Table 6-12** lists the ten invasive plant species believed to constitute the most serious problems and threats in the Ohio River Valley ecosystem. Of these, Japanese knotweed is overwhelmingly considered the most serious invasive plant species (USFWS 2000a and Morrison, personal communication).

Japanese knotweed (*Polygonum cuspidatum*) is an herbaceous plant introduced from Japan in the late 19th century, which has since become invasive, especially in riparian zones. According to studies cited in Kalisz and Dunn (2002), outside its native range, Japanese knotweed is male-infertile and propagates through long lateral rhizomes. Therefore, flood scour and human movement of soil easily disperse the plant. Once stands of Japanese knotweed become established, herbaceous plant species fail to survive under its dense canopy, and recruitment of woody species is impaired.

In a survey of navigation pools in the vicinity of Pittsburgh, PA, Kalisz and Dunn (2002) found Japanese knotweed comprised 11.5% of the abundance of all woody species and was more abundant than over 90% of the native species. They found it in areas in which it had not occurred only two years prior, confirming the species' ability to spread rapidly. The abundance of Japanese knotweed along the rivers surveyed, led the investigators to conclude that it is overtaking native riparian plant species in the region. Kalisz and Dunn also noticed a positive correlation between the abundance of introduced plant species and human disturbance of the riverbanks. Finally, they noted a high level of public recognition and concern about problems related to invasive exotic riparian plants, expressed at River Dialogue public forums held near Pittsburgh in 2001 and 2002.

TABLE 6-12
The Ten Most Problematic Invasive Exotic Plant Species Along the Ohio River (RM 0 to RM 437)

Common Name	Scientific Name
Tree of heaven	*Ailanthus altissima*
Garlic mustard	*Alliaria petiolata*
Japanese hop	*Humubus japonicus*
Japanese honeysuckle	*Lonicera japonica*
Tatarian honeysuckle	*Lonicera tatarica*
Japanese knotweed	*Polygonum cuspidatum*
Mile-a-minute	*Polygonum perfoliatum*
Giant knotweed	*Polygonum sachalinense*
Kudzu	*Pueraria montana var. lobata*
Multiflora rose	*Rosa multiflora*
Source: Morrison, Personal communication 2003.	

Purple loosestrife (*Lythrum salicaria*), an exotic species of serious concern in the northeastern U.S., is not included in the top ten list. Its distribution along the Ohio River mainstem is patchy, as favorable habitat is limited to narrow bands along mud flats (Morrison, personal communication).

6.8 INTERACTIONS WITH OTHER VECS

The following statement on the multiple functions of riparian areas succinctly connects RFR with several other VECs, including water quality, land use, threatened and endangered species, and recreation:

> Riparian areas provide essential life functions such as maintaining stream flows, cycling nutrients, filtering chemicals and other pollutants, trapping and redistributing sediments, absorbing and detaining floodwaters, maintaining fish and wildlife habitats, and supporting the food web for a wide range of biota. The future success of at least five national policy objectives -- protection of water quality, protection of wetlands, protection of threatened and endangered species, reduction of flood damage, and beneficial management of federal public lands -- depend on the restoration of riparian areas (NRC 2002):

As discussed in previous sections of this chapter, past development patterns have determined the present day configuration of riparian resources along the Ohio River. The interrelationship between riparian areas and human activity on the Ohio River is underscored by the fact that existing and potential future quality of the RFR is largely dependent upon management of the lock and dam navigation infrastructure, as well as upon on-the-ground decisions of how riparian resources will be used or protected. The extent, variety, and complexity of RFR along the Ohio River are significantly influenced by the amount of flow variability associated with the maintenance of pool elevations. Historically, flow control has focused on maintaining a minimum pool depth or minimizing flood peaks. In the future, the possibility of mimicking natural flow variations could be introduced so as to affect desired riparian habitat outcomes.

The potential value of flow variability to riparian habitats is recognized by the USFWS. Although the Ohio River Islands NWR has no direct control of water levels in the river, the USFWS advocates the resource benefits to be gained by water level management that mimics natural hydrological cycles. Where feasible, USFWS will manage water levels on Ohio River Island Refuge wetlands to mimic natural fluctuations and promote aquatic and wetland vegetation.

The future of riparian areas also is related to the management and potential development of privately owned land and to the demographics that, in turn, drive development. River transportation and traffic, which similarly are driven by demographics and market demands, also influence riparian areas in many ways, as indicated by the issues from project scoping **(see Table 6-1)**.

Water quality improvements have led to increases in boating and contact recreation. These recreation activities, however, cause potential bank erosion and other adverse effects on RFR, including development of marinas and other related businesses. On the other

hand, better water quality has improved riparian area aesthetics with regard to appearance and odor and has renewed interest in the Ohio River as a community asset. This renewed interest appears to be increasing the demand for more parks, bike trails and other green spaces along the river. Sustainable management of such lands to maintain or restore more diverse wildlife habitat could result in more functional riparian areas along the mainstem.

6.9 RELEVANT ACTIONS AFFECTING RIPARIAN/FLOODPLAIN RESOURCES

RFFAs were evaluated by members of the IWG, utilizing the RFFA Matrix for RFR (see Chapter 2 discussion of RFFA matrices). The Riparian RFFA Team formed subcommittees to address each of the five subVECs associated with the Riparian VEC: 1) terrestrial habitats, 2) wetlands, 3) riparian threatened and endangered species, 4) islands, and 5) the combined topic of floodplain hydrology, soils, and geology. SubVEC matrices were combined and evaluated, resulting in the identification of 15 RFFAs with potentially high importance (composite importance score $\geq$ 20) and 20 RFFAs with medium importance (composite importance score $\geq$ 15 - 19). These RFFAs are presented in **Table 6-13**.

The table also indicates the principal riparian function or functions affected positively or negatively by the proposed action, according to the following key:

H/S = affects hydrology and sediment dynamics
B/N = affects biogeochemistry and nutrient cycling
Ha = affects habitats and food web maintenance

The following discussion focuses on RFFAs ranked high and medium in the combined Riparian RFFA matrix. RFFAs are grouped according to their influence on riparian functions. It is important to bear in mind, however, that most actions have multiple interrelated effects on riparian functions. In fact, 22 RFFAs in **Table 6-13** are shown as affecting all the above mentioned riparian functions.

6.9.1 Actions Influencing Hydrology and Sediment Dynamics

A wide array of actions in and along the Ohio River influence riparian hydrology and sediment dynamics. Such actions are undertaken by the USACE, navigation industry, mining industry, and other river users.

Land-based activities that involve soil compaction, excavation, mining of mineral resources, or curtailment of periodic flows of water affect RFR by altering or eliminating water storage capacities, severing hydrological linkages, changing flow directions, velocities, variability, and sediment dynamics. Included in these activities are:

- lock extensions/replacements
- dam replacements/rehabilitation
- levees
- dry dams and other flood reduction projects off the mainstem
- channel modifications
- pool maintenance
- power generating facilities

- instream and floodplain sand and gravel mining, and limestone aggregate mining
- all types of floodplain development

All types of land development reduce the extent and functioning of riparian areas through land-use conversion and creation of hydrologic conditions that reduce aquatic habitat quality and lessen effectiveness of remaining riparian areas for water quality protection and other functions. Lock extensions or replacements and dam replacements or rehabilitation typically involve clearing of riparian areas during construction activities with impacts to local hydrology and habitat. Such impacts may be considered temporary; however, even with timely revegetation of a disturbed site, decades may elapse before riparian areas return to pre-disturbed conditions. Further, alterations in lock and dams can cause temporary or long-term alterations in river flow that may lead to erosion of riverbanks and nearby islands.

The impacts of residential, commercial, and industrial development on RFR are profound because of their long-term nature, the accompanying increase in imperviousness, and the development of related infrastructures that sever hydrological connections, permanently change soils, and fragment or eliminate habitat. The compaction of soils and replacement of vegetation by impervious rooftops, parking lots, and roads decreases infiltration, groundwater recharge, and groundwater contributions to streams, while increasing overland flow volumes and peak runoff rates which, in turn, contribute to erosion and nonpoint source pollution. Highway network and rail lines that support urban development, commerce, and large facilities such as power generating plants and other industrial sites further impact riparian areas by: 1) altering local topography, 2) changing infiltration and rerouting surface and groundwater, and 3) removing riparian vegetation.

One activity often stimulates another activity, compounding negative impacts. Floodplain development, for example, can create a demand for flood damage reduction structures such as levees and floodwalls that, subsequently, cause floodplain loss and severing of hydrologic connections. Levees alter connections between a channel and its RFR by changing the frequency, magnitude, and duration of overbank flows.

Ongoing maintenance of present pool elevation, superficially considered a rather passive activity, contributes to the loss of flow variability, which adversely affects riparian habitats, islands, soils, and floodplain hydrology. Similarly off-mainstem flood control dams and reservoirs dampen the magnitude of flood events. Natural flooding, in contrast, tends to rework channel sediments such that riparian areas continually gain and lose substrates, which contribute to their nature and productivity (NRC 2002).

Instream sand and gravel mining and channel maintenance dredging (ranked low in **Table 6-13**) also change sediment transport in the river channel, can eliminate or damage aquatic habitat, and may lead to island erosion and bank undercutting and failure, which, in turn, alters hydrology and compromises habitat and nutrient cycling. With instream sand and gravel mining, removal of large amounts of materials may induce channel down-cutting, which influences local groundwater patterns, frequency of overflows, bank stability, and the character of riparian vegetation (Collins and Dunne 1989; Kondolf 1995, as cited in NRC 2002).

To the rather limited extent that such activities may occur along the length of the mainstem, wetlands mitigation, ER projects, nonstructural flood damage reduction measures, and implementation of ES practices (rated high) can restore some floodplain hydrology functionality. Over time, storm water regulations also may contribute to restoration of functionality. Environmental awareness education, also rated high, could incrementally contribute to future protection or recovery of RFR.

Emergency streambank stabilization measures (ranked low) potentially prevent soil loss and sediment deposition, but may reduce hydraulic roughness along channel margins, thereby increasing flow velocities along banks during high flows, and often precluding survival of many riparian plant species (NRC 2002).

6.9.2 Actions Influencing Biogeochemistry and Nutrient Cycling

Actions in this category alter soil morphology and the ability of RFR to filter pollutants and trap sediments. Major transformations and transport processes associated with RFR include infiltration, deposition, filtration, adsorption, degradation, and assimilation. The importance of these mechanisms in controlling water quality depends on the extent and quality of RFR, as well as on local topography - all of which influence water retention time from upland areas. Included in actions influencing biogeochemistry and nutrient cycling are:

- agriculture
- silviculture
- public and private land acquisition and management, especially for heavy recreational use
- natural climatic events, especially floods, and
- the TMDL program (not listed in **Table 6-13**)

Nationwide and along the Ohio River mainstem, traditional agriculture is probably the largest contributor to the decline of riparian resources for several reasons:

1) Conversion of undeveloped land to agriculture has the potential to decrease infiltration and increase overland flow volumes and peak runoff rates.
2) Land conversion, consequently, may lead to high erosion rates that inundate RFR with sediment and limit their filtering functions.
3) Tile drainage of agricultural lands circumvents many biological processes that typically occur in riparian areas.
4) Transport of agricultural chemicals from uplands can negatively impact riparian fauna and flora, as well as downstream receiving waters.
5) Finally, livestock grazing results in loss of vegetation, compaction of underlying soils and dispersal of exotic plant species and pathogens, which have long-term CE on soil structures and the composition and productivity of plant and animal communities (NRC 2002).

In natural settings, RFR protect the soil surface. Further, the flora and fauna are constantly creating macropores, which help maintain high infiltration and percolation rates. Typical agricultural conversion to rowcrops and pasture exposes soil to raindrop impact and surface sealing, which decrease infiltration. Although agricultural tillage helps

maintain soil porosity, it does not achieve the porosity characteristic of undisturbed RFR. The 2002 Farm Bill includes cost share incentives and educational outreach efforts that promote the benefits of healthy riparian areas to agricultural activities, but traditional farm practices do not tend to change quickly.

The practice of silviculture likewise results in substantial structural and composition changes to RFR, especially when large tracts of standing timber are harvested or when the period between harvest operations is short (NRC 2002). In general, the impacts of forestry are most severe when forests are clear-cut or harvested right up to the streambank.

As with agriculture and silviculture, the development and use of public recreational facilities and private campgrounds and seasonal trailer parks can profoundly affect RFR and all their functions. A unique characteristic of riparian recreation areas is the concentration of human activities in often narrow strips of land and the potential for these activities to simultaneously affect both terrestrial and aquatic ecosystems. Heavy foot, animal, and vehicular traffic in riparian recreation areas cause soil compaction, destruction of soil biota, and increased erosion. Damage to riparian habitats can be incidental, as by overuse, or deliberate, as by replacement with impervious surfaces. Collectively, these actions also affect water quality by introducing sediments, bacteria, petrochemicals, pesticides, and refuse to adjacent water bodies. In some cases, the riparian aesthetics that made a site attractive for recreational use initially may be so severely compromised that neither the RFR nor recreation use itself can be sustained.

Because of their ability to move and modify soils and land forms, floods also affect riparian biogeochemistry and nutrient cycling. Floods tend to rework channel sediments causing riparian areas to gain and lose substrates in ways that define riparian composition and productivity. As with agriculture, floods affect all riparian functions. Floods, for example, influence habitat by helping to control the germination, establishment and long-term survival of seedlings. In the natural order, riparian vegetation in turn provides the ecological services of frictional resistance to flowing water and runoff during floods, creation of soil macropores through growth and decay, and streambank stabilization by roots.

The last action in this section, the TMDL program, was not ranked high or medium in **Table 6-13**. According to the NRC (2002), this program may eventually have a significant beneficial effect on RFR, because many TMDL implementation plans that have been developed require restoration of riparian areas as a measure to achieve needed reductions in nonpoint source pollution, thus returning to the major transformation and transport processes provided by RTR.

6.9.3 Actions Influencing Habitats and Food Web Maintenance

Almost all actions listed in **Table 6-13** affect riparian habitat function and food web maintenance. Animal life in riparian areas can be affected by direct disturbance, modification or destruction of habitat, pollution, exploitation (e.g., hunting and fishing), or introduction of pathogens. Impaired riparian habitats are also linked to degraded aquatic habitats as shading benefits and inputs of woody materials and nutrients to the aquatic ecosystem diminish. The structural diversity of native riparian plant communities creates a wide variety of feeding niches for both herbivores and carnivores. Many species utilize

RFR for movement, either as part of their home ranges or for short-term movements. In fact, short-term movements of small mammals and birds within riparian areas have been shown to aid in the cycling of nutrients between the aquatic environment and adjacent uplands (NRC 2002). RFR also provide food resources for animals throughout the food web. To illustrate the intricacy of such connections, a study cited in NRC (2002) indicated riparian vegetation not only is a primary food source for invertebrates but also serves as landing substrate for adult insects (e.g., stoneflies and mayflies) emerging from waterbodies. The insects in turn become food for migratory and resident birds in the floodplain.

As mentioned previously, all types of floodplain development, including ports, navigation structures, power plants, residences, industries, businesses, and recreation facilities negatively affect RFR directly by fragmentation, degradation, or complete elimination of habitat. Repercussions of these developments compound the effects on riparian habitat. For example, a study cited in NRC (2002) found that highways developed to serve floodplain facilities have ecological effects that extend as far as 600 m on each side of the road. New roads also become conduits for the dispersal of exotic plant species that alter native plant communities in riparian areas.

Among the RFFAs affecting habitat that have not been discussed in the two preceding sections are:

- nonstructural flood control measures
- pool maintenance
- barge queuing
- increased and dispersed barge traffic
- modification of Corps project for environmental improvement (as authorized by Section 1135 of WRDA 1986)
- ER projects
- floodplain sand and gravel mining and limestone aggregates mining
- environmental regulations and initiatives.

Nonstructural flood control measures include flood damage reduction practices that do not rely on dams or built structures. Examples include installation of riparian buffer strips along waterways and relocation of housing out of a floodplain. Both actions are potentially beneficial to RFR, as additional native habitat may be actively restored or allowed to return.

Table 6-13 rates pool maintenance as having the maximum impact on all components of RFR. The most apparent effect of pool maintenance is the loss of riparian structure and function due to inundation. A further deleterious effect on RFR relates to changes in river flows that alter flow seasonality, sediment dynamics, and moisture availability. Some riparian plants require drawdown periods for seed germination and seedling establishment. Cottonwood, a common component of riparian forests, is an example of a species that requires high flows that precede seed release and flow recession that permits seedling establishment at appropriate streambank elevations. As discussed previously, river regulation with pool maintenance has created embayments at the mouths of flooded tributaries along the Ohio mainstem. Embayments represent additional habitat that is static and differs from previously more abundant riverine habitat.

Although ranked low, barge queuing can adversely affect riparian habitat, including wetlands, if barges in queues are tied to trees or anchors and "deadmen" are placed. These concerns are heightened if queuing occurs along islands, where loss of trees can accelerate erosion and the consequent loss of limited island habitat. Likewise, increased and dispersed barge traffic, both ranked medium, are of concern because of wave-induced erosion and possible damage to riparian vegetation. Because vegetation of islands below the Newburgh and John T. Myers L/D have been affected by barge traffic, the dams will continue to be modified to allow for navigation over fixed weirs during flood events.

Modification of Corps projects for environmental improvements and ER projects are considered of high benefit to RFR. Of five broad habitat types considered, four are included in RFR – bottomland hardwood forests, islands, shorelines, and wetlands. The fifth habitat type, aquatic habitat, is linked to RFR and could benefit from riparian restoration efforts.

Floodplain sand and gravel mining and limestone aggregate mining directly fragment habitat and reduce riparian vegetation. Additional impacts of mining result from soil excavation and alteration of groundwater flows. Floodplain hydrology is further altered when mining operations end and excavated pits become flood storage areas.

Floodplain development, including marinas and small navigation projects that require Corps permits, if allowed, also negatively affect riparian habitat. Restrictions imposed on permits and evaluation of CE when permits are considered can help lessen such affects. GIS and other recent assessment tools used by the Corps also can increase accuracy and geographic comprehensiveness in projecting impacts to riparian areas.

Lastly, environmental awareness education and environmental sustainability practices offer positive benefits for RFR, but are voluntary actions that will require wider interest, acceptance, and practice before environmental benefits will be realized. Wetland mitigation banking and the Endangered Species Act also offer positive RFR benefits that are somewhat better defined and more site-specific.

TABLE 6-13
Combined RFFA for Riparian VEC

RFFA[1]	Time Period[2]	Probability[3]	Location[4]	Terrestrial habitat	Islands	Wetlands	Soils/Geol.	Floodplain hydrology	Importance[5]	Functions Influenced[6]
Navigation Investment Actions										
Lock Extensions/New Locks/Replacement or Rehabilitation	A	H	E	5	3	5	3	3	19	All
Dam replacement and/or rehabilitation[6]	A	H	E	5	5	5	5	5	25	All
Other Corps Actions										
Flood Damage Reduction Projects										

RFFA[1]	Time Period[2]	Probability[3]	Location[4]	Terrestrial habitat	Islands	Wetlands	Soils/Geol.	Floodplain hydrology	Importance[5]	Functions Influenced[6]
levees/floodwalls	A	M	E	5	3	5	3	5	21	
dry dams, other projects off mainstem	A	M	E	5	0	3	3	5	16	H/S, Ha
channel modifications				5	0	5	0	5	15	H/S, Ha
nonstructural measures (e.g., relocation)				5	3	5	0	5	18	Ha
Modification of Corps structures for environmental improvements (Sec. 1135)	A	L	E	5	5	5	3	1	19	Ha
Environmental restoration of aquatic ecosystems (Sec. 206)	A	L	E	5	5	5	3	3	21	Ha
ERP Projects - 5 categories	A	M	E	5	5	5	3	3	21	All
Port development (Sec. 107) and maintenance dredging	A	M	E	5	1	3	3	3	15	All
Pool maintenance[6]	A	H	E	5	5	5	5	5	25	H/S, Ha
"But for" Actions										
Commercial Navigation										
terminals	A	M	E	5	1	5	3	1	15	All
multi-modal sites	A	M	E	5	1	5	3	1	15	All
increased traffic				5	5	5	0	0	15	Ha
dispersed barge traffic				5	5	5	0	0	15	Ha
Instream sand and gravel mining	A	H	E	5	5	3	5	0	18	H/S, Ha
Floodplain sand and gravel mining	A	H	E	5	0	5	5	5	20	H/S, Ha
Limestone aggregates mining	A	H	E	5	0	3	5	5	18	H/S, Ha
Coal utilities	A	H	E	5	3	3	5	5	21	All
Other coal industries	A	H	E	5	0	3	5	5	18	All
Hydropower on dams	A	M	E	5	3	3	3	3	17	All
Recreation facilities - Construction and O&M				5	3	5	3	0	16	All
Actions by Others										
Public lands acquisition and management	A	H	U	5	5	5	5	0	20	B/N, Ha
Floodplain development										
residential	A	H	E	5	0	5	5	5	20	All
commercial	A	H	E	5	0	5	5	5	20	All
industrial	A	H	E	5	0	5	5	5	20	All
Private recreational - camps, docks, seasonal trailer parks[6]	A	H	E	5	5	3	5	1	19	B/N, Ha
Crossings - bridges	A	H	E	3	5	5	3	3	19	All
Silviculture	A	H	E	5	3	3	5	0	16	Ha
Agriculture	A	H	M,L	5	3	5	5	5	23	B/N, Ha
Natural Climatic Events										
floods	A	L	E	3	5	5	3	1	17	All

RFFA[1]	Time Period[2]	Probability[3]	Location[4]	Terrestrial habitat	Islands	Wetlands	Soils/Geol.	Floodplain hydrology	Importance[5]	Functions Influenced[6]
Regulatory Environment										
COE permitting programs	A	H	E	5	5	5	3	5	23	All
Small navigation projects	A	M	E	3	3	5	3	5	19	All
Environmental Awareness Education	A	H	E	5	5	5	5	5	25	All
Environmental sustainability practices	A	M	E	5	5	5	5	5	25	All
Lower Scored RFFAs										
Channel dredging/dredged material disposal				3	5	5	0	0	13	H/S, Ha
Emergency streambank stabilization (Sec. 14)	A	H	E	5	0	5	3	1	14	H/S, Ha
Fleeting areas/barge storage	A	M	E	5	3	5	1	0	14	H/S
Industrial users, excluding coal-related	A	H	E	5	0	3	5	0	13	All
Marina development & operation	A	H	E	3	3	3	3	0	12	B/N, Ha
Site remediation	A	L	E	3	1	5	3	1	13	All
Wetland Mitigation Banking	A	L	E	0	0	5	3	5	13	All
ESA (Endangered Species Act)	A	H	E	5	3	5	0	0	13	All

[1] Reasonably Foreseeable Future Actions

[2] Time period in which the RFFA may occur: 1 = within 10 years, 2 =10 - 25 years, 3 = 25 – 60 years, A = applicable all time periods

[3] Occurrence probability or likelihood RFFA will happen: H = high, M = medium, L = low

[4] Location or setting on river where RFFA is expected to occur: U = upper (Pittsburgh - Huntington), M = middle (below Huntington – Louisville), L = lower ((below Louisville - mouth), E = along entire length of river, SL = specific location, e.g., locks and dams, U = urban setting, R = rural setting

[5] Importance of RFFA = sum of subVECs. For individual Sub VEC: High = 5 points, Medium = 3 points, Low = 1 points, None = 0 points

6 Functions influenced: H/S = hydrology and sediment dynamics, B/N = biogeochemistry and nutrient cycling, Ha = habitat and food web maintenance

6.10 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

One of the seven environmental operating principles of the Corps is to strive to achieve environmental sustainability (ES). ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation, and maintenance to improve the quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of CE can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An analysis of environmental sustainability (AES) has been and is being used in several other

programmatic studies of the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps: (1) delineation of "common effects" on eight indicators of ES from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of three service areas provided by RFR, and their grouping, as appropriate; and (3) consideration of the "connections" among the common effects, the indicators, and the service area groups. The relationship among the three service areas (functional groups) and the eight indicators are summarized as follows:

- Hydrology and Sediment Dynamics

  -- adequacy of hydrologic connections between riparian areas and adjacent water bodies and uplands -- these connections are necessary for maintaining appropriate water flows and riparian storage of surface water and sediment

  -- capacity for water storage in the floodplain -- adequate capacity is needed in order to reduce downstream flood damages; such capacity can also facilitate the cycling and removal of undesirable chemical constituents prior to their movement to nearby streams and rivers

  -- water table and groundwater recharge -- shallow groundwater systems play a vital role in the subsurface flow of water to and from nearby streams and rivers, and local wetlands; this resource is also basic to groundwater usage and to the subsurface attenuation or movement of chemical contaminants

  -- sustainability of sediment dynamics -- natural movement of sediment from riparian areas to streams and rivers, and the continuing transport downstream; provides nutrients and bottom habitat materials for the aquatic ecosystem

- Biogeochemistry and Nutrient Cycling

  -- quality of soil structures -- adequate soil structures can aid in reducing erosion and providing a diverse floral setting for associated fauna

  -- capacity of riparian areas to intercept pollution -- attenuation of pollutant movement to nearby streams and rivers is beneficial to the aquatic ecosystem; such attenuation is a function of chemical and microbiological characteristics of the pollutants, soil structure and chemistry, and local hydrodynamic conditions

- Habitat and Food Web Maintenance

  -- integrity of riparian habitats -- integrity relates to the resiliency of habitats relative to hydrodynamic, climatic, biotic, and abiotic stresses; such integrity is a function of the type, size, and quality of the habitat, as well as the contiguous nature of the habitat

-- measures of biodiversity -- greater diversity is typically associated with more stable and properly functioning riparian ecosystems

The output of the AES consists of a qualitative (descriptive) discussion of the "connections", with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions -- what is the current ES for RFR, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable -- the composite conditions for the 8 indicators and the selected 3 service areas (functional categories) provided by RFR do not reflect conditions that would facilitate a healthy, diverse, and robust riparian zone along the majority of the Ohio River mainstem; further, there are no organized institutional controls and management measures for sustaining riparian areas.

- Marginally sustainable -- the composite conditions for the 8 indicators and the selected 3 service areas are problematic at several locations along the Ohio River; these problematic conditions are somewhat tenuous both in location and likelihood of occurrences, and there are uncertainties regarding specific quantitative measures of the indicators; therefore, the conditions are "borderline" regarding a healthy, diverse, and robust riparian zone along the majority of the Ohio River mainstem; further, while some institutional programs for riparian area management may be in place, they do not encompass all RFR.

- Sustainable -- the composite conditions for the 8 indicators and the 3 service areas reflect conditions that would facilitate a healthy, diverse, and robust riparian zone along the majority of the Ohio River mainstem; further, comprehensive institutional controls and management measures are in place to sustain RFR.

As noted in **Table 6-13**, the 35 RFFAs ranked as high (H) or medium (M) can be grouped into actions having effects on the three functional categories. These three groups of actions, along with the eight environmental indicators, and three functional categories, are displayed in **Tables 6-14 through 6-16**. **Table 6-14** includes 26 RFFAs that are anticipated to cause effects on the Hydrology and Sediment Dynamics functional group (service area). The connections between the 26 RFFAs and the four indicators for the group are summarized in terms of common anticipated effects. Finally, the right-most column summarizes the composite resulting effects on all three functional groups. In addition, pertinent conclusions are drawn relative to the ES of RFR. In general, the CE of the majority of the listed actions in **Table 6-13** would move the RFR away from a sustainable condition.

Table 6-15 relates to 23 RFFAs that are anticipated to affect the Biogeochemical and Nutrient Cycling functional group. The structure of **Table 6-15** is similar to that for **Table 6-14**. The information in **Table 6-15** also indicates that the CE of the majority of the RFFAs would move the RFR away from a sustainable condition.

Finally, **Table 6-16** highlights the CE of all 35 high and medium importance RFFAs relative to their affects on the Habitat and Food Web Maintenance functional group.

Again, the structure of **Table 6-16** is similar to that for **Tables 6-14 and 6-15**. Also, the CE on this functional group would move the RFR away from sustainability.

To summarize, **Tables 6-14 through 6-16** indicate that the high and medium importance RFFAs will have the following CE on the three functional groups:

- Regarding the Hydrology and Sediment Dynamics functional group, the RFFAs are expected to cause: (1) further disruptions and decreases in natural hydrologic connections; (2) changes in upstream to downstream flow patterns; (3) lowering (decrease) of the water storage capacity of the floodplain; (4) undesirable declines in the water table and recharge rates; (5) changes in flow patterns between aquifers and the river; (6) perturbations in the environmental movement of sediment; and (7) reductions in the inputs of nutrients and bottom habitat materials moving to the river.

- Regarding the Biogeochemical and Nutrient Cycling functional group, the RFFAs are expected to cause: (1) undesirable soil compaction; (2) reductions in the diversity of floral settings; and (3) reductions in the interception capacity of the riparian areas due to soil compaction and decreases in areas with diverse floral coverings.

- Regarding the Habitat and Food Web Maintenance functional group, the RFFAs are expected to cause: (1) reductions in the resiliency, size, quality, and contiguous nature of many existing riparian habitats and (2) decreases in the biodiversity and food web maintenance associated with numerous habitat areas.

TABLE 6-14
AES Tiers for Actions that Affect the Hydrology and Sediment Dynamics Functional Group

RFFAs that Affect Hydrology and Sediment Dynamics	Indicators for Hydrology and Sediment Dynamics	Composite Considerations for ES for Riparian/Floodplain Resources
(1) Lock extensions, new locks, replacement or rehabilitation (M) (see Note 1) (2) Dam replacement and/or rehabilitation (M)(see Note 1) (3) Levees/floodwalls (H) (see Note 1) (4) Reservoirs and other projects off mainstem (M) (see Note2) (5) Channel modifications (M) (see Note 2) (6) ERP projects (H) (see Note 1) (7) Port development and maintenance dredging (M) (see Note 1) (8) Pool maintenance (H) (see Note 2) (9) Commercial navigation -- terminals (M) (see Note 1) (10) Commercial navigation -- multi-modal sites (M) (see Note 1) (11) Instream sand and gravel mining (M) (see Note 2) (12) Floodplain sand and gravel mining (H) (see Note 2) (13) Limestone aggregates mining (M) (see Note 2) (14) Coal utilities (H) (see Note 1) (15) Other coal industries (M) (see note 1) (16) Hydropower on dams (M) (see note 1) (17) Recreation facilities (by others) -- construction and O&M (M) (see Note 1) (18) Floodplain development -- residential (H) (see Note 1) (19) Floodplain development	• Adequacy of hydrologic connections --. Hydrologic connections are disrupted and decreased in local riparian areas by RFFA numbers 1, 2, 3, 7, 9, 10, 17, 18, 19, 20, 21, and 23; such disruptions or decreases will occur in larger riparian areas as a result of RFFA numbers 12, 13, 14, and 15. Movement of water from upstream to downstream locations will be altered by RFFA numbers 4, 5, 7, 8, 11, 16, 21, 22, 23, and 24. Likely increases in hydrologic connections would occur from RFFA numbers 6, 25, and 26. Therefore, in summary, the cumulative effects of the listed RFFAs would be expected to be manifested as further disruptions and decreases in riparian area hydrologic connections to the Ohio River mainstem, and in changes in the upstream to downstream flow patterns of the Ohio River. • Capacity for water storage in the floodplain -- Small and local decreases in the water storage capacity of the floodplain would occur from RFFA numbers 1 and 17. Larger local decreases in the storage capacity would be expected from RFFA numbers 7, 9, 10, 13, 14, 15, 18, 19, 20, and 23. Imposed mitigation measures on 18, 19, and 23 could reduce the local decreases in storage capacity; further, increases could be achieved via the design features of retention basins and the use of Best Management Practices (BMPs). Local increases in floodplain water storage capacity would be expected to result from RFFA	• Maintenance of sufficient hydrology and sediment dynamics -- The RFFAs are expected to cause: (1) further disruptions and decreases in natural hydrologic connections, (2) changes in upstream to downstream flow patterns, (3) lowering (decrease) of the water storage capacity of the floodplain; (4) undesirable declines in the water table and recharge rates; (5) changes in flow patterns between aquifers and the River; (6) perturbations in the environmental movement of sediment; and (7) reductions in the inputs of nutrients and bottom habitat materials moving to the River. As a result, this functional group will move further away from contributing to sustainable conditions for the riparian/floodplain resources. • Facilitation of biogeochemical processes and nutrient cycling -- Because of the reduced maintenance of the functions of the hydrology and sediment dynamics component of ES, the facilitation of biogeochemical processes and nutrient cycling as a component of ES will decline. • Provision of diverse habitat and maintenance of related food webs -- Because of the

RFFAs that Affect Hydrology and Sediment Dynamics	Indicators for Hydrology and Sediment Dynamics	Composite Considerations for ES for Riparian/Floodplain Resources
-- commercial (H) (see Note 1) (20) Floodplain development -- industrial (H) (see Note 1) (21) Crossings -- bridges (M) (see Note 1) (22) Floods (M) (see Note 1) (23) COE permitting programs (H) (see Note 1) (24) Small navigation projects (M) (see Note 1) (25) Environmental Awareness Education (H) (see Note 1) (26) Environmental sustainability practices (H) (see Note 1)	numbers 3, 6, 12, 22, 25, and 26; with RFFA number 8 having the potential to increase or decrease the capacity. No effects on water storage capacity would be expected from RFFA numbers 2, 4, 5, 11, 16, and 24. Therefore, in summary, the cumulative effects of the listed RFFAs would be expected to lower (decrease) the water storage capacity of the floodplain of the Ohio River mainstem. • Water table and groundwater recharge -- Groundwater recharge will be decreased in local alluvial aquifers as a result of RFFA numbers 1, 17, and 21; such decreases are expected in larger areas from RFFA numbers 7, 9, 10, 14, 15, 18, 19, 20, and 23 (lesser decreases could occur with implementation of designed retention basins and BMPs for 18, 19, and 20). Increased recharge in larger areas would be expected from RFFA numbers 3, 6, 12, 25, and 26. Local physical alterations to water tables could occur from RFFA numbers 2, 13, and 24. Increases in groundwater usage and consequent lowering of the water table could occur in local areas via usage of the resource by RFFA numbers 7, 9, 10, 14, and 15. Declines in groundwater usage would be expected from numbers 25 and 26. Finally, changes in natural temporal patterns and quantities of groundwater inflow to the Ohio River, along with patterns of river flow moving into alluvial aquifers would result from RFFA numbers 4, 5, 8, 11, 16, and 22. Therefore, in summary, the cumulative effects of the listed RFFAs would be expected to cause undesirable declines in the water table and recharge rates, and also cause changes in the natural patterns	reduced maintenance of the functions of the hydrology and sediment dynamics component of ES, the provision of conditions for diverse habitats and maintenance of related food webs will decrease. • Conclusion relative to ES of riparian/floodplain resources -- The composite effects summarized herein are such that the riparian/floodplain resources would move away from a more sustainable condition. This situation creates an immediate need for planning and implementing an institutional program for riparian area management for the Ohio River mainstem.

RFFAs that Affect Hydrology and Sediment Dynamics	Indicators for Hydrology and Sediment Dynamics	Composite Considerations for ES for Riparian/Floodplain Resources
Notes: (1) this RFFA also affects the Bio-geochemistry and Nutrient Cycling functional group, and the Habitats and Food Web Maintenance functional group (2) this RFFA also affects the Habitats and Food Web Maintenance functional group	of flows between the aquifers and the Ohio River. • Sustainability of sediment dynamics -- Disruptions of sediment movement from riparian/floodplain areas into the Ohio River would be expected from RFFA numbers 3, 7, 9, 10, 12, 13, 14, 15, 17, 18, 19, 20, and 23. Further, decreases in nutrient input and bottom habitat materials for aquatic ecosystems are anticipated from RFFA numbers 3, 18, 19, 20, and 23. Disruptions in downstream sediment movement would occur from RFFA numbers 1, 2, 4, 5, 7, 8, 11, 16, 21, 22, and 24. RFFA numbers 25 and 26 would be expected to promote natural sediment movement from the riparian/floodplain areas. Finally, the influence of RFFA number 6 would be dependent on the location, type, and extent of the ecological restoration program; the effects could be beneficial or detrimental, or they could be so small as to be classified as no effect. Therefore, to summarize, the cumulative effects of the listed RFFAs would be expected to cause disruptions in the environmental movement of sediments, and to cause reductions in nutrient inputs and bottom habitat materials moving to the Ohio River.	

TABLE 6-15
AES Tiers for Actions that Affect the Biogeochemistry and Nutrient Cycling Functional Group

RFFAs that Affect Biogeochemistry and Nutrient Cycling	Indicators for Biogeochemistry and Nutrient Cycling	Composite Considerations for ES for Riparian/Floodplain Resources
(1) Lock extensions, new locks, replacement or rehabilitation (M) (see Note 1) (2) Dam replacement and/or rehabilitation (H) (see Note 1) (3) Levees/floodwalls (H) (see Note 1) (4) ERP projects (H) (see Note 1) (5) Port development and maintenance dredging (M) (see Note 1) (6) Commercial navigation -- terminals (M) (see Note 1) (7) Commercial navigation -- multi-modal sites (M) (see Note 1) (8) Coal utilities (H) (see Note 1) (9) Other coal industries (M) (see Note 1) (10)Hydropower on dams (M) (see Note 1) (11)Recreation facilities (by others) -- construction and O & M (M) (see Note 1) (12)Public lands acquisition and management (H) (see Note 2) (13)Floodplain development -- residential (H) (see Note 1) (14)Floodplain development -- commercial (H) (see Note 1) (15)Floodplain development -- industrial (H) (see Note 1) (16)Private recreational -- camps, docks, seasonal trailer parks (M) (see Note 2) (17)Crossings -- bridges (M) (see Note 1) (18)Agriculture (H) (see Note 2) (19)Floods (M) (see Note 1)	• Quality of soil structures -- Compaction of local soils would take place due to RFFA numbers 1, 2, 11, 16, 17, 20, and 21; compaction over larger areas would occur due to numbers 3, 5, 6, 7, 8, 9, 13, 14 and 15. In general, soil compaction is undesirable relative to riparian areas. Reductions in the diversity of floral settings, and their related faunal species, would be expected from RFFAs 3, 5, 6, 7, 8, 9, 13, 14,15and 18. Several RFFAs would be expected to enhance soil quality and promote diverse habitats; the RFFA numbers include 4, 12, 19, 22, and 23. Hydropower on dams (number 10) would not be expected to cause effects. Therefore, in summary, the majority of the cumulative effects would be associated with undesirable soil compaction ad reductions in the diversity of floral settings. • Capacity of riparian areas to intercept pollution -- Decreases in the interception capacity would be expected for local areas subjected to RFFA numbers 1, 2, 11, 16, and 17; similar decreases over larger areas would be expected for numbers 3, 5, 6, 7, 8, 9, 13, 14, 15, and 20. Potential increases in pollution interception capacity would be expected from RFFA numbers 4, 12, 18, 19, 22, and 23. Hydropower on dams (number 10) and small navigation projects (number 21) are not anticipated to alter interception capacity. In summary, the	• Facilitation of biogeochemical processes and nutrient cycling -- The RFFAs are expected to cause: (1) undesirable soil compaction; (2) reductions in the diversity of floral settings; and (3) reductions in the interception capacity of the riparian areas due to soil compaction and decreases in areas with diverse floral coverings. As a result, this functional group will move further away from contributing to sustainable conditions for the riparian/floodplain resources. • Maintenance of sufficient hydrology and sediment dynamics -- Because of greater soil compaction and losses of floral diversity, overland runoff will be increased, and greater soil erosion is likely. Accordingly, the hydrology and sediment dynamics functional group as a component of ES will decline. • Provision of diverse habitat and maintenance of related food webs -- Because of the reduced facilitation of the functions of the biogeochemistry and nutrient cycling component of ES, the provision of conditions for diverse habitats and maintenance of related food webs will decrease. • Conclusion relative to ES of riparian/floodplain resources -- The composite effects summarized herein are such that the riparian/floodplain resources would move away from a more sustainable

RFFAs that Affect Biogeochemistry and Nutrient Cycling	Indicators for Biogeochemistry and Nutrient Cycling	Composite Considerations for ES for Riparian/Floodplain Resources
(20)COE permitting programs (H) (see Note 1) (21)Small navigation projects (M) (see Note 1) (22)Environmental Awareness Education (H) (see Note 1) (23)Environmental sustainability practices (H) (see Note 1) Notes: (1) this RFFA also affects the Hydrology and Sediment Dynamics functional group, and the Habitats and Food Web Maintenance functional group (2) this RFFA also affects the Habitats and Food Web Maintenance functional group	majority of the 23 listed RFFAs would be expected to cause reductions in the interception capacity; the primary mechanisms would probably be associated with soil compaction and reductions in floral coverings.	condition. This situation creates an immediate need for planning and implementing an institutional program for riparian area management for the Ohio River mainstem.

TABLE 6-16
AES Tiers for Actions that Affect the Habitat and Food Web Maintenance Functional Group

RFFAs that Affect Habitat and Food Web Maintenance	Indicators for Habitat and Food Web Maintenance	Composite Considerations for ES for Riparian Floodplain Resources
(1) Lock extensions, new locks, replacement or rehabilitation (M) (see Note 1) (2) Dam replacement and/or rehabilitation (H) (see Note 1) (3) Levees/floodwalls (H) (see Note 1) (4) Reservoirs and other projects off mainstem (M) (see Note 2) (5) Channel modifications (M) (see Note 2) (6) Nonstructural measures (M) (7) Modification of Corps structures for environmental improvements (Sec.1135) (M)	• Integrity of riparian habitats -- The resiliency, size, quality, and contiguous nature of local riparian habitats will be reduced by RFFA numbers 1, 2, 14 (islands), 22, 27, and 28; such reductions in larger riparian habitat areas will occur as a result of numbers 3, 10, 12, 13, 17, 18, 19, 20, 24, 25, 26, 29, 30, and 32. Increases in habitat fragmentation would be expected from RFFA	• Provision of diverse habitat and maintenance of related food webs -- The RFFAs are expected to cause: (1) reductions in the resiliency, size, quality, and contiguous nature of many existing riparian habitats; and (2) decreases in the biodiversity and food web maintenance associated with numerous habitat areas. Accordingly, this

RFFAs that Affect Habitat and Food Web Maintenance	Indicators for Habitat and Food Web Maintenance	Composite Considerations for ES for Riparian Floodplain Resources
(8) Environmental restoration of aquatic ecosystems (Sec.206) (H) (9) ERP projects (H) (see Note 1) (10) Port development and maintenance dredging (M) (see Note 1) (11) Pool maintenance (H) (see Note 2) (12) Commercial navigation -- terminals (M) (see Note 1) (13) Commercial navigation -- multi-modal sites (M) (see Note 1) (14) Commercial navigation -- increased traffic (M) (15) Commercial navigation -- dispersed barge traffic (M) (16) Instream sand and gravel mining (M) (see Note 2) (17) Floodplain sand and gravel mining (H) (see Note 2) (18) Limestone aggregates mining (M) (see Note 2) (19) Coal utilities (H) (see Note 1) (20) Other coal industries (M) (see Note 1) (21) Hydropower on dams (M) (see Note 1) (22) Recreation facilities (by others) -- construction and O & M (M) (see Note 1) (23) Public lands acquisition and management (H) (see Note 3) (24) Floodplain development -- residential (H) (see Note 1) (25) Floodplain development -- commercial (H) (see Note 1) (26) Floodplain development -- industrial (H) (see Note 1) (27) Private recreational -- camps, docks, seasonal trailer parks (M) (see Note 3) (28) Crossings -- bridges (M) (see Note 1) (29) Silviculture (M) (30) Agriculture (H) (see Note 3) (31) Floods (M) (see Note 1) (32) COE permitting programs (H) (see Note 1) (33) Small navigation projects (M) (see Note 1) (34) Environmental Awareness Education (H) (see Note 1) (35) Environmental sustainability	numbers 24, 25, and 26 (all three involve floodplain developments). Enhancement of the resiliency, size, quality, and contiguous nature of riparian habitats is anticipated from RFFA numbers 4, 7, 8, 9, 23, 31, 34, and 35. Finally, no effects are anticipated for aquatic environment actions involving numbers 5, 6, 11, 15, 16, 21, and 33. In summary, the majority of the cumulative effects would be associated with declines in the resiliency, size, quality and contiguous nature of existing riparian habitats. • Measures of biodiversity -- The biodiversity of local riparian habitats will be reduced by RFFA numbers 1, 2, 14 (islands), 22, 27, and 28; such biodiversity declines in larger habitat areas will occur as a result of numbers 3, 10, 12, 13, 17, 18, 19, 20, 24, 25, 26, 29, 30, and 32. Enhancement of the biodiversity of larger habitats is anticipated from RFFA numbers 4, 7, 8, 9, 23, 31, 34, and 35. No effects are anticipated for aquatic environment actions involving numbers 5, 6, 15, 16, 21, and 33. Pool maintenance (number 11) could cause beneficial or adverse effects, depending upon location and specific water level fluctuations. To summarize, the majority of the cumulative effects are associated with reductions in the biodiversity, and associated food web maintenance, of riparian habitat areas.	functional group will be reduced in its ability to positively contribute to sustainable conditions for riparian/floodplain resources. • Maintenance of sufficient hydrology and sediment dynamics -- Because of declines in both the integrity and biodiversity of habitats, and the maintenance of food web relationships, the more natural conditions for hydrology and sediment dynamics will be reduced. Accordingly, this functional group will be reduced in its contribution to sustainable riparian/floodplain resources. • Facilitation of biogeochemical processes and nutrient cycling -- Because of the declines in the habitat and food web maintenance functional group, reductions will also occur in biogeochemical processes and nutrient cycling. • Conclusion relative to ES of riparian/floodplain resources -- The composite effects summarized herein are such that the riparian/floodplain resources would move away from a more sustainable condition. This situation creates an immediate need for planning and implementing an institutional program for riparian area management for the Ohio River mainstem.

RFFAs that Affect Habitat and Food Web Maintenance	Indicators for Habitat and Food Web Maintenance	Composite Considerations for ES for Riparian Floodplain Resources
practices (H) (see Note 1) Notes: (1) this RFFA also affects the Hydrology and Sediment Dynamics functional group and the Biogeochemistry and Nutrient Cycling functional group (2) this RFFA also affects the Hydrology and Sediment Dynamics functional group (3) this RFFA also affects the Biogeochemistry and Nutrient Cycling functional group		

6.11 CONCLUSIONS

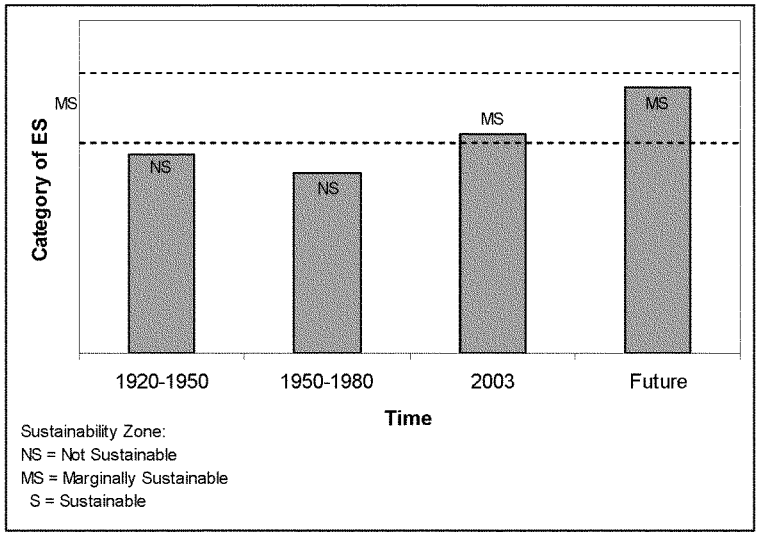
Based upon the above-described historical information, the actions and effects, the changes in the eight indicators for the effects, and the three functional groups related to the ES of RFR, the sustainability can be characterized and depicted in **Figure 6-1** as follows:

- In the time period prior to 1920, and continuing up to about 1950, the RFR can be classified as "not sustainable" due to relatively rapid losses of riparian habitats and their functions, the lack of knowledge of the importance of these resources to both terrestrial and aquatic ecosystems, and to the essential absence of any institutional programs to manage or control riparian areas. Further, the lack of awareness of environmental services performed by RFR coupled with ongoing floodplain development, especially in the upper and middle river, led to the loss and fragmentation of valuable RFR along the Ohio mainstem before such resources could be well-documented.

- In the time period from 1950 to 2000, worsened "not sustainable" conditions occurred in the first several decades as a result of still more disruptions and losses of riparian areas. However, recent decades have included an increasing awareness of riparian services, including regulation of wetlands, a highly productive riparian component. The establishment of the Ohio River Islands National Wildlife Refuge has slowed the disappearance of another riparian habitat type, islands, and also has brought greater visibility to riparian resources of the Ohio mainstem embayments. These initiatives suggest the current status of RFR may be moving toward "marginally sustainable". Accompanying these initiatives is an increasing recognition that institutional programs must be established to protect RFR.

- Regarding the future, the growing awareness of environmental services performed by RFR, as well as increasing demand for river corridor enhancement and protection for passive recreation may help move RFR toward a more sustainable future. However, it is less certain if environmental regulations and institutional programs will be in place to support RFR sustainability and stem fragmentation and loss of RFR from development along the Ohio River mainstem. Pending the establishment of such protective measures, RFR can be expected to remain within the range of "marginally sustainable."

FIGURE 6-1
ES of Riparian Resources



- An important issue is the need for institutional programs for riparian area management. While it is beyond the scope of this chapter to completely explore the types of programs and considerations related to their implementation, examples of program features include, but are not limited to (NRC 2000):

  (1) requiring impact identification and mitigation via the NEPA process,

  (2) designation of special management areas on public lands,

  (3) regulation of activities on privately-owned riparian areas,

  (4) utilization of incentives such as cost-sharing, low-cost loans, or tax reductions to encourage the use of BMPs on riparian areas, and

  (5) the purchase of privately owned riparian lands, either in fee or by easement, for public management.

The above examples are only illustrative. Further, they are not mutually exclusive; they can be used in combination.

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Chapter 7
AIR QUALITY

7.1 CONTENTS

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References

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7.2 DEFINITION OF AIR QUALITY

This chapter considers how Cumulative Effects (CE) of human use of the Ohio River have influenced air quality and what air quality impacts may be anticipated in the foreseeable future. In the Ohio River Mainstem Systems Study (ORMSS), air quality refers to ambient or outdoor air that is safe to breathe by all members of the general population, including young children, elderly citizens and other "at risk" individuals such as asthmatics. Air quality standards are used to assess the levels at which a particular area is being protected; specific air quality parameters evaluated in the ORMSS are discussed in the section titled Indicators of Air Quality. The effects of air quality on other Valued Evironmental Components (VECs) are integrated in the section titled Interactions with Other VECs.

7.3 OBJECTIVES AND SCOPE OF THE AIR QUALITY STUDY

7.3.1 Introduction

This chapter assesses the system-wide cumulative air quality impacts of all likely major navigation improvements along the mainstem of the Ohio River during the period from 2000 - 2070. Air quality impacts that are directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the US Army Corps of Engineers (Corps) and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFA. These future actions include the major navigation improvements identified in this study, other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies, actions by non-governmental entities, and predictions of general economic expansion and development.

The results of the Cumulative Effects Assessment (CEA) are intended to contribute to two levels of subsequent public debate; whether the impacts of the RFFAs constitute acceptable outcomes for the affected resources, and the manner in which the proposed navigation improvements contribute to those outcomes.

7.3.2 Geographic Scope

For the Air Quality section of the CEA, the geographic area of focus for air pollutant sources includes the region directly served by Ohio River barge transport, e.g., counties adjacent to the main stem of the Ohio River. The contribution of these sources to both local and regional air quality concerns is discussed in this chapter.

7.3.3 Time Frame

The established time frame for this CEA project is 1920 to 2070. The earlier date approximates the initiation of Corps lock and dam construction activities on the Ohio River. The latter date approximates the end of the 60-year planning horizon encompassed by the ORMSS.

7.4 INPUT FROM PUBLIC SCOPING MEETINGS

A series of 12 public scoping meetings was held during Summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state or local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. A more detailed discussion of the scoping meetings is presented in Section 2 (Methodology) of this report.

185 people attended the meetings and over 200 vocal comments were recorded from the question and answer sessions. These comments accounted for the large majority of

input. Additional comments were obtained from 19 questionnaires and several letters that were submitted. Only one comment directly addressed air quality, noting the "importance of continued air quality improvements as a high priority."

7.5 INDICATORS OF SUSTAINABILITY

National air quality standards are established by the USEPA under authority of the Clean Air Act (CAA). CE are explicitly recognized in the establishment of air quality standards. In addition to tracking compliance with the standards, the CAA requires that USEPA continually evaluate the effectiveness of the standards in protecting human health and other resources. New standards, as well as revisions of existing standards, are developed and implemented to maintain these protections.

7.6 LAWS, REGULATIONS, ORDINANCES, AND PROGRAMS

7.6.1 Impacts of Air Pollution

Air pollutants that are currently contributing to significant air quality issues in the Ohio Valley region include; ground level ozone (O_3), particulate matter ($PM_{2.5}$, PM_{10}), oxides of nitrogen (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOCs).

NOx combines with VOC to produce ground level O_3, which is a threat to human health in a growing number of Ohio River communities. Primary sources of NOx include motor vehicles, power plants, and other industrial combustion sources. VOCs are produced from motor vehicles, chemical plants, refineries, factories, and some consumer or commercial products. Short-term (1-3 hours) and prolonged (6-8 hours) exposures to O_3 are associated with increased hospital admissions and emergency room visits for respiratory distress, especially among active children and adults with a pre-existing susceptibility such as asthma. Exposures to O_3 contribute to respiratory infections, lung inflammation, decreased lung function, chest pains, and cough. Ozone also impacts agriculture, commercial forestry, and urban parks; causing increased susceptibility to disease, pests, and other stresses.

SO_2 and NOx are the primary causes of acid rain, which impacts people and ecosystems throughout the midwest and northeast, and in southeastern Canada. Coal-fired power plants are the primary source of SO_2. Other sources include metal smelting, other industrial processes, and combustion of sulfur containing fuels such as diesel. Acidification of soils, lakes, and streams has caused the destruction of commercial and recreational fisheries, degraded agricultural and forest production, and accelerated corrosion of buildings and monuments (USEPA, August 2000, 2001a, b).

NOx, VOC, and SO_2 are also major precursors to fine particulate matter ($PM_{2.5}$). These gases interact with other compounds in the air to form fine particles. $PM_{2.5}$ also consists of dry particles emitted directly from sources such as fuel combustion by motor vehicles, power plants, and industrial facilities. Fine particles are associated with deep penetration into the lungs, contributing to increased hospital and emergency room visits, increased respiratory symptoms and disease, decreased lung function, and even premature death. By comparison, course particles (PM_{10}) are emitted by vehicle travel on unpaved roads, materials handling, crushing and grinding operations, and windblown dust.

Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions, such as asthma.

Carbon Monoxide (CO) is a potentially poisonous by-product of motor vehicle exhaust, and high concentrations typically occur in areas with heavy traffic congestion. Peak CO concentrations typically occur in winter when CO emissions are greatest and nighttime inversion conditions concentrate the pollutants. Motor vehicle engine design standards and "winter blend" reformulated gasoline for problem areas have combined to reduce average CO ambient concentrations by 57% in the past 20 years, with an estimated 93% reduction in the number of exceedances of the standard.

7.6.2 Air Quality Standards and Regulations

National Ambient Air Quality Standards (NAAQS) have been established by USEPA for the seven categories of air pollutants presented in **Table 7-1** (USEPA, June 2004). New standards for ground level ozone and fine particulate matter are included in this table.

In 1997, USEPA revised the NAAQS for ozone by setting a new 8-hour 0.08 ppm standard. Legal challenges held up implementation of the new standard until the U.S. Supreme Court affirmed USEPA on Feb. 27, 2001. USEPA reviewed the results of the litigation and conferred with states and other interested parties to determine the approach and schedule for implementing the ozone standard. The new standard, including the identification of areas designated "attainment" or "nonattainment," was formally implemented in April, 2004.

In 1997, USEPA added new $PM_{2.5}$ standards to the existing particulate standards. These new standards were upheld in the Feb. 27, 2001 Supreme Court ruling. USEPA cannot start implementing the 1997 fine particle standards until three years of data have been collected to determine which areas are not attaining the standards. The fine particle monitoring network was completed in 2000. Designations of attainment and nonattainment areas under this new standard went into effect on April 5, 2005. An ambient monitoring and analysis program for $PM_{2.5}$ that was conducted from 1987 through 2001 found the highest concentrations of $PM_{2.5}$ to be occurring in the east. The primary source of these particles was sulfates from utility and industrial boilers throughout the region. Some of the highest concentrations were measured in KY, TN, WV, and VA.

Air quality is monitored primarily by the states, but with substantial assistance of larger monitoring networks supported by USEPA and others. States are additionally responsible for establishing and maintaining emission inventories that quantify the location, concentration, and net emissions from major, minor, and mobile sources statewide. The combination of monitoring and inventory management is the primary basis for tracking air quality trends and the progress of emission control efforts.

Areas failing to meet one or more NAAQS are identified as nonattainment. Nonattainment areas may be individual communities or multi-county regions, depending on the type and extent of the pollution problem. Nonattainment areas typically cross state lines wherever population centers are located near such borders.

TABLE 7-1
National Ambient Air Quality Standards

Pollutant	Primary Standards.	Averaging Times	Secondary Standards.
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour[1]	None
	35 ppm (40 mg/m^3)	1-hour[1]	None
Lead	1.5 µg/m^3	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter (PM_{10})	50 µg/m^3	Annual[2] (Arith. Mean)	Same as Primary
	150 ug/m^3	24-hour[1]	
Particulate Matter ($PM_{2.5}$)	15 µg/m^3	Annual[3] (Arith. Mean)	Same as Primary
	65 ug/m^3	24-hour[4]	
Ozone	0.08 ppm	8-hour[5]	Same as Primary
	0.12 ppm	1-hour[6]	Same as Primary
Sulfur Oxides	0.03 ppm	Annual (Arith. Mean)	-------
	0.14 ppm	24-hour[1]	-------
	-------	3-hour[1]	0.5 ppm (1300 ug/m^3)

[1] Not to be exceeded more than once per year.

[2] To attain this standard, the expected annual arithmetic mean PM10 concentration at each monitor within an area must not exceed 50 ug/m^3.

[3] To attain this standard, the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15 ug/m^3.

[4] To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 65 ug/m^3.

[5] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.

[6] (a) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is <= 1, as determined by appendix H. (b) The 1-hour standard is applicable to all areas notwithstanding the promulgation of 8-hour ozone standards under Sec. 50.10. On June 2, 2003, (68 FR 32802) EPA proposed several options for when the 1-hour standard would no longer apply to an area.

Source: U. S. Environmental Protection Agency, June, 2004, http://www.epa.gov/air/criteria.html

States have primary responsibility for establishing management goals and implementing programs to achieve the standards. States manage nonattainment programs in their portion of multi-state areas. State programs are formally documented as State Implementation Plans (SIPs) which are subsequently approved by USEPA. Additionally, air quality programs in some areas have been delegated by the states to local authorities. In the Ohio River Valley ORV these include the Department of Environmental Services in Cincinnati, OH; the Allegheny County Health Department in Pittsburgh, PA; and the Louisville Metro Air Pollution Control District.

In actual practice, programs to reduce air pollution include a complex mixture of national, state, local, and multi-jurisdictional initiatives. Basic emission standards for automobiles and gasoline are national programs as are forthcoming regulations addressing diesel engines and fuels. Inspection programs to insure vehicles are properly maintained to minimize emissions are administered by the states and implemented at the local level. More recently, a variety of market oriented initiatives such as emission caps for a specific group of sources and trading of emission allotments have been implemented. These are intended to allow the group of sources to utilize more cost-effective strategies to reduce net emissions from the group. The acid rain program addresses SO_2 and NOx emissions from coal-fired electric utilities nationwide. Three additional programs address NOx from utilities and other industrial sources throughout the midwest and northeast.

7.7 PAST TO CURRENT BASELINE CONDITIONS

7.7.1 Historic Air Quality Conditions

Information about air quality impacts during the earlier decades of the study period is primarily anecdotal. Comprehensive monitoring of emissions and research addressing the relationships between human health and air pollution dates from the early 1970's, corresponding to the first generation of national air quality laws and regulations (e.g., CAA of 1970) and establishment of USEPA and state level air agencies. The year 1980 serves as a convenient benchmark of the point at which many regulations began to take effect and air emission quantities began to level off or decline. It is frequently the earliest date from which reliable trend data is reported by USEPA.

The extensive and diverse industrial development in the Ohio River Valley (ORV) continued up to about 1970 without regulation of air emissions. Extensive highway development from 1945 through 1970 contributed to the growing popularity of the automobile for personal transportation as well as development of an extensive commercial trucking industry. Leaded gasoline and diesel fuel from these mobile sources added concentrations of lead, VOC, CO, NOx, PM and other pollutants to the air. While detailed local or regional estimates are difficult to establish, USEPA estimates that national emissions of NOx increased 690% between 1900 and 1970. During the same period, VOC emissions increased 260% and SO_2 increased by 210% (USEPA, Aug. 2000). Air quality trends in the ORV probably approximate these national trends with the exception of SO_2, which was very heavily concentrated in the ORV. Localized impacts of smog, PM, and lead attracted the most attention during the two decades of debate that preceded finalization of national air quality regulation in the early 1970's. Long-range transport and atmospheric chemical interactions that contributed to acid rain, O_3, and other impacts were less obvious, but the earliest legislation established the monitoring and research programs that led to better understanding of these processes.

One of the earliest programs to improve air quality focused on the automobile. Beginning in the mid-70's, all new vehicles sold in the U.S. were required to have catalytic converters, which reduced emissions and required the vehicles to operate on unleaded gasoline. Additional engine design and performance standards also contributed to reduced emissions of VOC and CO. Subsequent fuel efficiency standards reduced emissions by increasing the number of miles traveled per gallon of fuel consumed. Significant progress

towards improved air quality was gradually achieved over about 15 years as the previous generation of leaded vehicles was gradually retired.

Many local air pollution problems are the result of concentrated populations and local weather patterns that concentrate pollutants over a period of several days. This is especially true of O_3 nonattainment areas in the ORV. Transportation management is one of the primary strategies at the local level for nonattainment communities, as well as for communities trying to maintain their attainment status. Vehicle inspection programs are a fundamental means of assuring that owners perform routine maintenance to keep their vehicle emissions in compliance. Communities can also require the use of reformulated fuels that burn more efficiently and emit fewer pollutants. Support of mass transit programs is motivated, in part, to reduce vehicle emissions.

Local program efforts are supplanted with emergency procedure approaches when local air quality threatens to exceed compliance thresholds. Local authorities may encourage or require reduced activities by public agencies, local industries, area sources, and individuals until air quality improves.

In general, regional conditions in the ORV reflect the national pattern for overall improvement in air quality. **Table 7-2** illustrates the progress of 42 areas in the ORV designated nonattainment since 1992. A total of 31 out of the 42 areas have achieved attainment redesignation. Between 1970 and 1999, emissions of the six NAAQS pollutants had decreased by 31 percent nationwide. These advances were achieved in concert with significant economic and population growth. During the same time period, U.S. Gross Domestic Product increased 147%, vehicle miles traveled increased 140%, and the U.S. population increased by 33%. Since 1970, national emissions from all of the NAAQS pollutants have decreased, with the exception of NOx. Between 1970 and 1999, emissions of NOx increased 17%. The majority of this increase can be attributed to heavy-duty diesel vehicles and coal-fired power plants (USEPA, Aug. 2000).

TABLE 7-2
Attainment History in the Ohio River Valley

State County	Pollutant	Area Name	Nonattainment in Year	Redesignation to Attainment
Indiana	1-Hr Ozone	Louisville, KY-IN	92 93 94 95 96 97 98 99 00 01	11/23/2001
Floyd Co				
Vanderburgh Co	1-Hr Ozone	Evansville, IN	92 93 94 95 96 97	12/9/1997
Kentucky	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (KY Portion)	92 93 94 95 96 97 98 99 00 01 02	8/30/2002
Boone Co				
Boyd Co	1-Hr Ozone	Huntington-Ashland, WV-KY	92 93 94	6/29/1995
Boyd Co	SO2	Boyd County (part), KY	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Bullitt Co	1-Hr Ozone	Louisville, KY-IN	92 93 94 95 96 97 98 99 00 01	11/23/2001
Campbell Co	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (KY Portion)	92 93 94 95 96 97 98 99 00 01 02	8/30/2002
Daviess Co	1-Hr Ozone	Owensboro, KY	92 93 94	1/3/1995

State County	Pollutant	Area Name	Nonattainment in Year	Redesignation to Attainment
Greenup Co	1-Hr Ozone	Huntington-Ashland, WV-KY	92 93 94	6/29/1995
Hancock Co	1-Hr Ozone	Owensboro, KY	92 93 94	1/3/1995
Jefferson Co	1-Hr Ozone	Louisville, KY-IN	92 93 94 95 96 97 98 99 00 01	11/23/2001
Kenton Co	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (KY Portion)	92 93 94 95 96 97 98 99 00 01 02	8/30/2002
Livingston Co	1-Hr Ozone	Paducah, KY	92 93 94	4/10/1995
Oldham Co	1-Hr Ozone	Louisville, KY-IN	92 93 94 95 96 97 98 99 00 01	11/23/2001
Ohio	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (OH Portion)	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Butler Co				
Clermont Co	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (OH Portion)	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Columbiana Co	1-Hr Ozone	Columbiana Co, OH	92 93 94	3/10/1995
Gallia Co	SO2	Addison Township (Gallia County), OH	92 93 94 95 96 97 98 99 00	7/5/2000
Hamilton Co	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (OH Portion)	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Jefferson Co	1-Hr Ozone	Steubenville, OH	92 93 94	3/10/1995
Jefferson Co	PM-10	Jefferson Co, OH	92 93 94 95 96 97 98 99 00	1/10/2001
Jefferson Co	SO2	Steubenville & Mingo Junction, OH	92 93 94 95 96 97 98 99	9/29/1999
Warren Co	1-Hr Ozone	Cincinnati-Hamilton, OH-KY (OH Portion)	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Washington Co	SO2	Waterford Township, OH	92 93 94	10/21/1994
Pennsylvania	CO	Pittsburgh, PA	92 93 94 95 96 97 98 99 00 01 02	1/13/2003
Allegheny Co				
Allegheny Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001
Allegheny Co	PM-10	Clairton & 4 Boroughs, PA	92 93 94 95 96 97 98 99 00 01 02 03	10/14/2003
Allegheny Co	SO2	Hazelwood, PA	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Beaver Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001
Butler Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001
Fayette Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001
Washington Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001
Westmoreland Co	1-Hr Ozone	Pittsburgh-Beaver Valley, PA	92 93 94 95 96 97 98 99 00 01	11/19/2001

State County	Pollutant	Area Name	Nonattainment in Year	Redesignation to Attainment
West Virginia	PM-10	Follansbee, WV	92 93 94 95 96 97 98 99 00 01 02 03	10/27/2003
Brooke Co				
Brooke Co	PM-10	Weirton, WV	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Cabell Co	1-Hr Ozone	Huntington-Ashland, WV-KY	92 93 94	12/21/1994
Hancock Co	PM-10	Weirton, WV	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Hancock Co	SO2	New Manchester-Grant Mag. Dis (Hancock), WV	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Hancock Co	SO2	Weirton, WV	92 93 94 95 96 97 98 99 00 01 02 03	/ /
Wayne Co	1-Hr Ozone	Huntington-Ashland, WV-KY	92 93 94	12/21/1994
Wood Co	1-Hr Ozone	Parkersburg, WV	92 93 94	9/6/1994

Source: U. S. Environmental Protection Agency, June, 2004

7.7.2 Current Air Quality in the ORV

The current status of air quality in the ORV as of June, 2004 is summarized in **Table 7-3** and **Figures 7-1 and 7-2**. As indicated in **Table 7-3**, 10 counties or subareas in 4 states continue to be designated as non-attainment for ozone (based on the 1-hour standard), PM_{10}, or SO_2. The new 8-hour standard for ozone has resulted in designation of 37 counties in 5 states. All of the nonattainment counties are within or adjacent to standard metropolitan statistical areas for major cities within the Ohio River corridor.

In addition to the 8-hour ozone standard, the new standard for $PM_{2.5}$ placed several localities in the ORV into nonattainment status. Formal designation of nonattainment counties for $PM_{2.5}$ occurred in April, 2005, however some of these will be eligible for delisting after submittal and USEPA review of 2002-2004 monitoring data.

These new standards will require some localities to continue or reinstate air quality regulatory programs from earlier periods when they were in noncompliance status (e.g., Pittsburgh and Northern Kentucky) while others will be required to implement regulatory programs for the first time. As summarized above, programs for 8-hour O_3 and $PM_{2.5}$ would primarily focus on transportation management, vehicle inspections, public education, and emergency procedures. In some cases, nonattainment localities may acquire the authority to impose stricter emission limits for NOx, SO_2, VOC, and $PM_{2.5}$ from stationary sources such as printers, distilleries, dry cleaners, industrial boilers, and related sources.

Emission standards or emission reduction programs at the national or multi-state regional level will play a critical role in helping all local programs achieve their air quality objectives. While most of these programs are currently in some stage of implementation, other program elements and impacts will be realized in the near to long-term future. These initiatives are discussed below in the Future Air Quality Section.

FIGURE 7-1
Ohio River Counties Designated Nonattainment for 8-Hour Ozone Standard

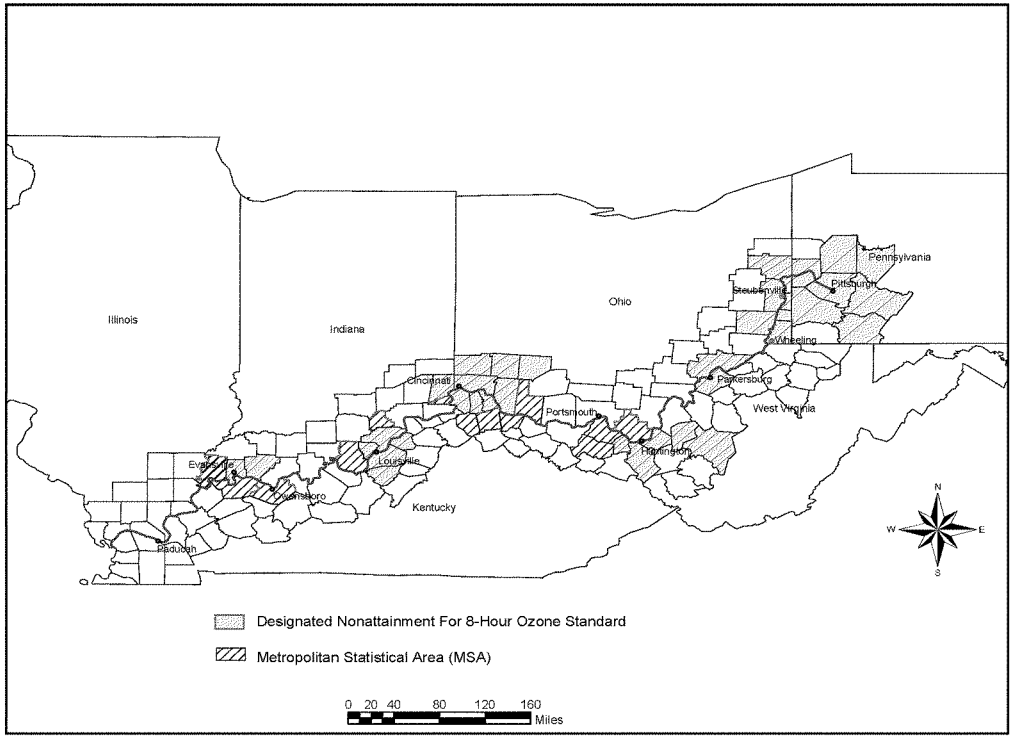

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FIGURE 7-2
Ohio River Counties Designated for Other Nonattainment Criteria

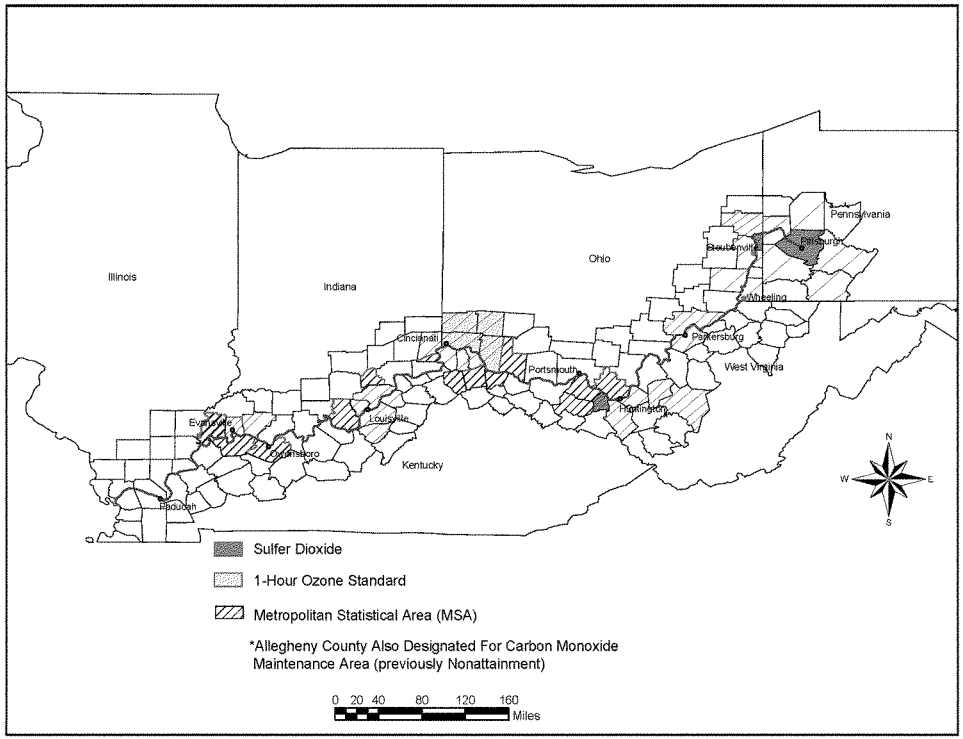

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TABLE 7-3
Summary of ORV Nonattainment Counties

State	Nonattainment Area Name	Counties	Classification	Maximum Attainment Date (8-hour Ozone, from June 15, 2004)
Boundary Designations for 8-hour Ozone Standard				
Pennsylvania	Pittsburgh-Beaver Valley, PA	Allegheny Armstrong Beaver Butler Fayette Washington Westmoreland	Basic	June 2009
West Virginia	Charleston, WV	Kanawha Putnam	Basic	June 2009
	Huntington-Ashland- KY-WV	Cabell Wayne	Basic	June 2009
	Parkersburg-Marietta, OH-WV	Wood	Basic	June 2009
	Steubenville-Weirton, OH-WV	Brooke Hancock	Basic	June 2009
	Wheeling, OH-WV	Marshall Ohio	Basic	June 2009
Kentucky	Cincinnati-Hamilton, OH-KY-IN	Boone Campbell Kenton	Basic	June 2009
	Huntington-Ashland, KY-WV	Boyd	Basic	June 2009
	Louisville, KY-IN	Bullitt Jefferson Oldham	Basic	June 2009
Ohio	Cincinnati-Hamilton, OH-KY-IN	Butler Clermont Hamilton Warren Clinton	Basic	June 2009
	Steubenville-Weirton, OH-WV	Jefferson	Basic	June 2009
	Youngstown-Warren-Sharon, PA-OH	Columbiana	Basic	June 2009
	Wheeling, WV-OH	Belmont	Basic	June 2009
	Parkersburg-Marietta, WV-OH	Washington	Basic	June 2009
Indiana	Louisville, KY-IN	Clark Floyd	Basic	June 2009
	Evansville IN-KY	Vanderburgh Warrick	Basic	June 2009
	Cincinnati-Hamilton OH-KY-IN	Dearborn (P)	Basic	June 2009
Boundary Designations for 1-hour Ozone Standard				
Ohio	Cincinnati-Hamilton OH-KY-IN	Butler Clermont Hamilton Warren	Moderate	

State	Nonattainment Area Name	Counties	Classification	Maximum Attainment Date (8-hour Ozone, from June 15, 2004)
Boundary Designations for Carbon Monoxide Maintenance Areas (Previously Nonattainment)[1]				
Pennsylvania	Pittsburgh, PA	Allegheny		
Boundary Designations for Sulfur Dioxide				
Pennsylvania	Hazelwood, PA	Allegheny	Primary	
West Virginia	Weirton, WV	Hancock	Primary, Secondary	
	New Manchester-Grant Mag. Dis	Hancock	Primary	
Kentucky	Boyd County (Part), KY	Boyd	Primary	
Boundary Designations for PM_{10}				
West Virginia	Weirton, WV	Brooke Hancock	Moderate	
[1]No ORV counties or sub areas are designated nonattainment for CO, NO_2, or Lead.				
Source: U. S. Environmental Protection Agency, June, 2004				

7.7.3 Current Air Emissions in the ORV

Recent emission inventories (USEPA, 1999) for every county adjacent to the Ohio River were aggregated to produce an emission inventory for the ORV (**Table 7-4**). The category 'marine vessels' includes all watercraft activities on the Ohio River and tributaries within the adjacent counties. In addition to all aspects of barge traffic (tows underway, port, and fleeting operations), this category includes dredging operations, recreational boating activity, and commercial excursion boating.

TABLE 7-4
Emission Inventory for Ohio River Corridor (1999)

EMISSIONS	CO	NO_X	SO_2	PM_{10}
Marine vessel emissions (tons) from counties adjacent to the Ohio River	6,246	59,430	25,081	3,216
Total emissions (tons) from counties adjacent to the Ohio River	2,557,184	1,253,044	2,182,054	336,708
% Of emissions originating from marine vessels in counties adjacent to the Ohio River	0.24	4.74	1.15	0.96

Source: U. S. Environmental Protection Agency, 1999

The most significant emissions associated with marine vessels are NOx, as would be expected from a source group dominated by diesel engines. The emission rates reported here for the ORV are consistent with other estimations of marine diesel contributions to emission inventories in port and waterway areas (USEPA, 1999a, b). For the ORV inventories of total emissions, the most significant contributions of NOx come from coal-fired utilities and highway transportation.

A study published by USEPA (Sept. 1999b) calculated emission factors from diesel engines for commercial marine emissions on inland waterways. The emission factors are expressed as emissions per ton-mile of barge freight and incorporate an adjustment for the percentage of barges returning empty. This makes it possible to calculate emissions for tows underway on any reach of the Ohio River where the total tonnage of barge freight has been recorded. Emissions from tows underway were calculated for each L&D on the Ohio River and are presented in **Table 7-5**.

The emission totals from **Table 7-4** for NOx, PM, and CO can be compared to the marine vessel emission totals from **Table 7-5**. For NOx, the 'tons underway' calculation represents 45 per cent of total emissions from marine vessels. The remaining 55 per cent includes tug emissions from fleeting operations and port activities, dredging, recreational boating activity, and commercial excursion boating. Regarding the percent of the total emissions shown in Table 6, NO_x from "tows underway" comprise 2.1% of the annual NO_x inventory, while PM is 0.38% and CO is 0.12% of their respective inventories.

TABLE 7-5
Emission Inventory for Tows Underway

L&D Project	Length (miles)	1998 tonnage (000's)	NOx E/yr (tons)	PM E/yr (tons)	CO E/yr (tons)	VOC E/yr (tons)
L&D 53	23.7	97,695	1388	66	165	33
L&D 52	20.4	97,695	995	47	118	24
Smithland	72.5	84,606	1823	87	217	43
Myers	69.9	74,151	2439	116	290	58
Newburgh	55.4	64,131	1856	88	221	44
Cannelton	113.9	54,386	2127	101	253	51
McAlpine	75.3	52,867	2311	110	275	55
Markland	95.3	56,119	2212	105	263	53
Meldahl	95.2	63,739	2805	134	334	67
Greenup	61.8	70,636	2562	122	305	61
Byrd	41.7	57,855	1383	66	165	33
Racine	33.6	40,517	705	34	84	17
Bellville	42.2	48,688	853	41	101	20
Willow Is.	35.3	44,766	801	38	95	19
Hannibal	42.2	47,627	853	41	102	20
Pike Is.	29.8	43,027	716	34	85	17
New Cumberland	22.7	35,425	430	20	51	10
Montgomery	18.4	26,866	255	12	30	6
Dashields	7.1	24,563	122	6	15	3
Emsworth	6.2	23,153	104	5	12	2
Ohio River Total	962.6		26,739	1,273	3183	637
% of Total Emissions Shown in Table 7-4			2.1	0.38	0.12	

Notes
Emission factors: NOx = 0.00042 kg/ton-mile; PM = 0.00002 kg/ton-mile; CO = 0.00005 kg/ton-mile; HC = 0.00001 kg/ton-mile
Source: U. S. Army Corps of Engineers (3), April 2000 and U. S. Environmental Protection Agency, Sept. 1999b.

7.8 INTERACTIONS WITH OTHER VALUED ENVIRONMENTAL COMPONENTS

The public health impacts of degraded air quality constitute the most significant interaction of air quality with other VECs. The importance of this interaction is reflected in the extent to which air quality regulations focus on improved health standards.

Air quality also interacts significantly with recreational and cultural resource values. Visibility impairment can detract from the enjoyment of urban or rural parks, river viewscapes, and cultural features. Corrosion from acid rain results in permanent damage to cultural features and reduces the quality of recreational experiences associated with impacted cultural features.

Corrosion from acid rain also impacts transportation structures such as bridges and overpasses and generally affects broader socioeconomic values through impacts to building facades, agriculture, forest, and aquatic resources. Air pollution impacts to natural systems within the ORV are generally attenuated by the buffering capacity of the region's deep soils and forest cover. Downwind areas such as the Adirondack Mountains Region of New York have less buffering capacity and are more susceptible to forest and aquatic resource impacts. Interactions between air quality and other VECs are summarized in **Table 7-6**.

TABLE 7-6
Interactions of Air Quality Factors with Other VECs

VEC	Factors & Impacts	Past/Present Trends	Future Trends	Comments
Recreation	Particulate emissions and ozone formation can impair visibility.	Viewscapes, recreational quality have benefited from improved air quality.	Appears likely present air quality will be maintained or improved.	Haze from coal burning, other sources persists throughout Ohio River corridor.
Cultural Resources	Corrosive impacts of acid rain.	Loss or degradation of grave markers, building facades, historic artifacts.	Improved air quality should reduce rate of degradation.	Continuing impact of damaged resources (no recovery).
Health & Safety	Respiratory infections, lung inflammation, decreased lung function, asthma	Improved air quality contributes to improved public health	Shift of focus to air quality in buildings (mold, air conditioning impacts).	Ozone monitoring and alerts to minimize health impacts of short term air quality degradation episodes.
Transport-ation	Role of transportation as major source. Corrosive impacts of acid rain.	Modification of cars, trucks, and vehicle fuels (gasoline).	Modification of diesel fuels, vehicles and equipment.	Minimal application to date of travel restrictions, regulation of transportation infrastructure.
Aquatic and Riparian Resources	Degradation impacts of acid rain.	Loss of fisheries, forest diversity, soil productivity.	Resource recovery in response to reduced deposition rates.	Impacts most prominent to downwind resources (PA, NY, New England).

VEC	Factors & Impacts	Past/Present Trends	Future Trends	Comments
Socio-economic Resources	Development restrictions in non-attainment areas, regional health care costs.	Emission controls, industrial process modifications, new source performance standards.	Impacts, restrictions minimized in response to improved air quality.	Air quality regulations can also spur improved production efficiencies, modernization of equipment.

7.9 RELEVANT ACTIONS AFFECTING AIR QUALITY

RFFAs were evaluated for air quality issues utilizing the RFFA Matrix (see Exhibit B, Procedure and Methods, for discussion of RFFA matrix). The matrix evaluation process resulted in identification of five RFFAs with high importance for air quality issues and an additional 15 that were rated as having medium importance. Results of the RFFA evaluation are summarized in **Table** 7-7 and discussed in further detail in text following the table.

TABLE 7-7
RFFA Cumulative Effects Matrix for Air Quality VEC

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Impact	Impor-tance[5]
Navigation Investment Actions					
Lock Extensions/New Locks/Replacement or Rehabilitation	A	H	SL	-	M
L&D operation and maintenance	A	H	SL	-	L
Non-structural navigation improvements	A	H	SL	+	M
Dam replacement and rehabilitation	A	H	SL	-	L
Other Corps Actions					
Port development (Sec. 107) and maintenance dredging	A	H	SL	-	M
"But for" Actions					
Commercial Navigation					
barge queuing	A	H	SL	-	H
fleeting areas/barge storage	A	H	SL	-	M
terminals	A	H	SL	-	M
multi-modal sites	A	H	SL	-	M
increased traffic	A	H	E	-	M
Instream sand and gravel mining	A	H	SL	-	M
Floodplain sand and gravel mining	A	H	SL	-	M
Limestone aggregates mining	A	H	SL	-	M
Coal utilities	A	H	SL	-	H
Other coal industries	A	M/L	SL	-	M
Industrial users, excluding coal-related	A	H	SL	-	H
Actions by Others					
Floodplain development					
Residential	A	H	SL	-	M
Commercial	A	H	SL	-	M
Industrial	A	H	SL	-	M

RFFA[1]	Time Period[2]	Occurrence Probability[3]	Location on River[4]	Impact	Impor-tance[5]
Regulatory Environment					
More stringent quality standards for environmental media	A	H	E	+	H
Pollutant source control	A	H	E	+	H
Emissions trading	A	H	SL	+	M
[1] Reasonably Foreseeable Future Actions					
[2] Time period in which the RFFA may occur: 1 = within 10 years, 2 = in 10 - 25 years, 3 = in 25 - 60 years, A = applicable for all time periods					
[3] Occurrence probability or likelihood RFFA will happen: H = high, M = medium, L = low					
[4] Location or setting on river where RFFA is expected to occur: E = along entire length of river, SL = specific location, e.g., locks and dams					

7.9.1 Direct Action Sources of Air Pollution

This section discusses air emissions that may occur as a direct result of project actions. These direct actions include lock construction and maintenance, navigation system operation and maintenance, other direct actions by the Corps, and direct actions by others. Potential emissions from each class of activities are summarized. In addition, the potential relationship between direct emissions and the With Project or Without Project alternative is assessed.

7.9.1.1 Construction of Lock Chamber Extensions.

Two primary classes of air emissions may be expected to occur as a result of the lock chamber projects described in **Table 7-7**. Particulate (PM) and combustion emissions from the construction site are discussed here. Emissions from commercial tow traffic delayed by site construction activities are discussed in the "Direct Action by Others" section.

Construction of the lock chambers requires establishment of parking and maintenance areas for equipment, burning of cleared vegetation, a lay-down yard for materials, disposal areas for excess soil and rock, and some earthwork where portions of the new lock chamber connect with the riverbank. Potential dust problems are controlled through a variety of standardized Best Management Practices (BMPs) such as seeding, periodic wetting of bare surfaces, or wind screens. These practices are routinely employed as needed to minimize nuisance dusts and PM emissions at Corps construction sites. Other potential sources of air pollution from construction include dust from concrete removal (sawing or blasting) and from concrete batch plants (if needed onsite). Concrete batch plants normally require a state air emissions permit.

The diesel engines that power bulldozers, crawler tractors, cranes, generators, and other equipment are the primary source of combustion air emissions at most construction sites, while gasoline powered equipment accounts for the remainder. Emissions from these sources include NOx, VOC, CO, sulfur oxides (SOx), and PM. This has traditionally been an unregulated class of combustion equipment, and large projects that require substantial equipment operations can produce locally significant quantities of air pollutants.

Air emissions from a construction site are subject to state and local air quality regulations (including rights of inspection and enforcement), and contractors may be

required to obtain an air emissions permit in some cases. Except for unusual cases, such permit conditions are fairly straightforward, requiring use of BMPs appropriate to the scale of operations, maintenance of equipment in good working order to minimize unnecessary emissions, and prohibition of open burning of construction wastes. In certain situations (e.g., a large project in a heavily populated area) there may be provisions for additional control or restriction of construction activities during ozone seasons when pollution is a problem or during ozone alert conditions.

7.9.1.2 Lock Maintenance, Repair, and Rehabilitation

The ongoing commercial use of the lock and dam facilities will require periodic upkeep and maintenance. This will include major and minor repairs of both primary locks and auxiliary locks. As existing locks age, the need for such repairs becomes more frequent. The frequency of repairs also increases in proportion to ongoing increases in the amount of commercial traffic (and resultant use of the lock chambers) on the Ohio River.

Each lock repair event will produce the same types of air quality impacts as was described above for lock construction projects. Construction site and equipment emissions will be smaller, in proportion to the reduced scale of the repair activity. If the repairs require lock closures, emissions attributable to delayed barge traffic will be proportional to the period of time that the locks are closed.

Maintenance and repair events would also continue to be required following completion of lock extension projects. However, completion of lock extensions can reduce repair activities and associated air quality impacts in several ways. First, it may be feasible to schedule some lock extensions so as to eliminate an auxiliary chamber repair event. Second, each extension creates a lock in new condition, allowing for a longer time interval between the auxiliary chamber repair events. The original full-sized lock will be required to do less work, since the total number of cycles can now be shared equally between the two full sized locks, allowing for a longer time between the main chamber repair events (U. S. Army Corps of Engineers (1), April, 2000). Finally, increased capacity would allow improved lockage efficiency during future repairs, thus minimizing barge queuing impacts associated with such repairs.

7.9.1.3 Operations

Locks and dams (L&D) on the Ohio River are operated by electrical power and produce no direct air emissions. Lights, loudspeakers, and instrumentation are also generally operated by electric power and also produce no direct air emissions. L&D facilities may have back up power facilities such as diesel powered generators on site. This type of equipment may require a state-issued basic or "source registration" permit which allows for periodic testing, emergency operation, and listing in local emission inventories. Additional air emissions result from L&D employees driving their vehicles to the site and maintenance operations such as lawn mowing. This amount of air emissions attributable to operations is constant for all levels of lock activity.

Dredging to maintain the nine-foot navigation channel in the Ohio River is a significant component of L&D operations. Diesel emissions from dredging operations emit the same types of pollutants (NOx, VOC, and PM) as do engines on linehaul and

harbor towboats. However, these emissions account for only a small proportion of total towboat emissions. Additionally, navigation channel dredging occurs at locations remote from L&Ds and would not be expected to change with lock improvements.

7.9.1.4 Other Direct Actions by U.S. Army Corps of Engineers

The Corps conducts other actions with potential air quality impacts. These include the full spectrum of maintenance and repair of all components of the navigation system infrastructure other than the locks. These ongoing activities (and their attendant air quality impacts) will occur independently of the lock maintenance or extension activities addressed by this study and are not expected to cause significant delays of towboat traffic.

The largest of these activities involves major rehabilitation of the dams (as opposed to rehabilitation of lock chambers). While the timing of rehabilitation projects is subject to numerous variables, this activity primarily corresponds to the useful life cycle of the dam. Of the 20 dams currently on the river, 6 have been rehabilitated in the past two decades, at an average age of 60 years following their initial construction. With a life cycle of 60 years, all of the dams currently on the Ohio River may require major rehabilitation during the 60-year cycle of the study period.

Air emissions from dam rehabilitation projects will be similar to construction site and construction equipment emissions described previously for lock extension projects. The activities will be subject to the same state and local permit requirements. Air emission quantities from these projects would likely be comparable to rehabilitation or new construction of interstate interchanges, office buildings, or other major projects occurring over a several month period.

7.9.2 Direct Actions by Others

7.9.2.1 Commercial Navigation

Commercial towboats operating on the Ohio River can be classified into two general categories; large towboats that move the fleets of barges up and down the river (linehaul) and smaller harbor tows operating in the ports and major fleeting areas. Linehaul towboats are typically powered by marine diesel engines of 1,500 hp to 8,000 hp and maneuver tows of up to 15 barges up and down the river. Harbor towboats assemble and disassemble the barge tows within the fleeting areas, assembling individual tows according to their delivery destination. Some barge tows may be assembled and delivered to a single destination, but many contain a mix of commodities with various assembly and delivery points. The harbor towboats add or remove individual barges to these mixed tows while the linehaul towboats maintain control of the primary tow (USEPA, Sept. 1999a).

The marine diesel engines that power these towboats emit NOx, PM, SO_2 and VOC. This has until recently been an unregulated source, but regulations applicable to new and remanufactured engines took effect in 2004 (USEPA, Nov. 1999b). These emissions are treated in this study as a direct consequence of both the existing navigation system and proposed project actions because it is the existence and maintenance of the lock and dam system that makes commercial barge traffic possible on the Ohio River.

One of the reasons that emissions from marine diesel engines have not previously been regulated is that they were considered a relatively minor source when compared to other mobile source classifications. However, as progress has occurred in the control of emissions from other sources, the relative contribution from marine diesel engines has increased. While a very busy river port such as St Louis, Cincinnati, or Pittsburgh may exhibit the highest concentrations of river towboat activity, the linear nature of river transportation means that some degree of activity will be maintained throughout the river corridor area. Additional concentrations of river towboats occur when towboats are forced to queue up due to lock construction, repairs, or general traffic congestion. Finally, several smaller population centers including Evansville, IN and Parkersburg WV (see Table 3), are now classified as nonattainment areas under the revised ozone (O_3-8hr) standards (USEPA, June 2004). While barge tug emissions may be insignificant in a large population center such as St Louis, a similar level of emissions would have a relatively larger effect in the smaller population centers.

7.9.2.2 Towboat Traffic at Locks

Linehaul towboat emissions need to be examined in the context of general commercial traffic levels and in the specific instance of queuing delays associated with lock construction, repairs, and congestion. The relationship between queuing delays, current levels of commercial traffic on the Ohio River, and projected growth of commercial traffic are discussed in greater detail in Section 8 of the SIP Main Report and in the Economics Appendix to the SIP. These studies generally conclude that projections for long term growth of commercial towboat traffic will occur independently of lock and dam navigation improvements on the Ohio River: the existing transportation system has excess capacity, allowing traffic to grow in response to economic demand for barge deliverable commodities.

Queuing delays occur as a result of general traffic congestion and/or due to lock closures for repair or extension. Construction of lock extensions on the lower river dams will require long term closure of the 600' auxiliary locks and periodic, shorter duration closures of the 1200' primary locks. Replacement of the 360' locks with larger locks at the three upper river sites would result in a similar degree of curtailment of lockage services. Since the existing 600' main chamber is the landward lock at these upper river sites, they would remain in service during construction of new locks riverward of the auxiliary chambers. Linehaul towboats that are delayed by such closures will emit excess pollutants in proportion to the delay times. These excess emissions may be concentrated in specific locales due to queuing in close proximity to the closed locks.

For the Myers lock extension project, 3 separate closures of the 1200' main chamber are predicted over the 30-month course of project construction. These closures total 11 days, or an annual average of 4.4 days, which is comparable to the average annual closure of 3.1 days/year over the 29 years that the Myers lock has been in operation (U. S. Army Corps of Engineers (1), April, 2000). The Greenup locks are much older and have a history of longer and more frequent closures of the 1200' main chamber, resulting in an annual average of 23 days of closure. The main chamber of Greenup is projected to be closed 17 days in five different events over the 35 month projected construction period to extend the auxiliary chamber. In addition, the main chamber will close for 12 hours a day for an interval of 39 days.

Linehaul tows that are delayed by construction closures or by repair events emit excess pollutants in proportion to the delay times. Air quality impacts from diesel sources directly attributable to lock extension activities would increase in proportion to delay times created by the construction activity. Following completion of the lock extension, air quality impacts directly attributable to maintenance and repair activities would decrease in proportion to the expected reduction of repair activity. The relationship between these competing air quality impacts is addressed quantitatively in the "Cumulative Effects" section of this chapter. Queuing delays associated with traffic congestion also would significantly decrease following completion of lock extensions since the new chamber capacity would minimize the need for queuing.

7.9.2.3 Barge loading/unloading and other intermodal operations.

These activities include transfer of coal, limestone, sand & gravel, gypsum, grains and other bulk materials. PM emissions are the primary air pollutant from the bulk handling processes (conveyors, open stockpiles, gravel separation, and coal blending) associated with loading and unloading barges. Loading facilities are also typically a minor source of exhaust emissions because the equipment is powered by diesel engines.

Each individual barge loading/unloading facility normally operates under the requirements of a state or local air permit. Permit conditions typically include measures to minimize fugitive dust emissions; for example through the stipulation of equipment maintenance standards, and a variety of BMPs such as wetting stock piles and conveyance points to control dusts. New USEPA regulations address diesel fuel formulations and engine performance standards, and compliance with these regulations will reduce emissions from combustion sources (USEPA, August 1998 and Nov. 2000). Barge loading operations located in nonattainment areas may be subject to closer monitoring or somewhat more stringent standards than would occur at loading sites in attainment areas.

Continued expansion of existing facilities and the establishment of new facilities can be expected to occur in response to general economic/population expansion and subsequent growth in loads carried by barge transport. As mentioned previously, traffic projections indicate that barge traffic growth will occur independently of navigation improvements. Therefore, it can be expected that expansion or addition of barge loading facilities will occur independently of navigation improvements.

7.9.3 Indirect Action Sources of Air Pollution

Indirect actions include activities which derive some benefit from the existence of the improved navigation system. However, these activities would likely have developed in some related form without navigation system improvements and would be expected to persist with or without maintenance or additional improvements to the system.

7.9.3.1 Industrial Development

Many industries in the ORV are to some degree dependent on the existence of an efficient and reliable navigation system. This includes industries that may never have shipped via barge and have no plans for doing so. In fact, some of the most highly dependent industries on waterway transportation do not ship on the rivers, but depend on

the cost-savings that it provides to their suppliers, making them both more competitive. The waterway transportation system allows for lower transportation costs, and, therefore, lower delivered costs of basic raw materials; most importantly coal, stone, ores, and chemicals, to secondary producers of goods such as electricity, coke, specialty chemicals, and construction materials. In turn, these industries generally induce demand for tertiary producers of items like steel coils and slabs, aluminum, and paper products, which are then used in factories that produce final consumer goods such as automobiles, appliances, utensils, packaging, and food products (U. S. Army Corps of Engineers, April, 2000).

Steady growth of waterway traffic on the Ohio River System (ORS) over the past 60 years provides indisputable evidence of basin shipper's dependence on the system. With the exception of export demands for coal and grain, the preponderance of commodities shipped on the waterway are relatively unaffected by changes in waterway transportation costs. Both raw material production facilities and the downstream production facilities they supply represent major capital investments. More importantly for this study, these investments represent a long-term commitment to the waterway, a commitment that is likely not to waiver over 20-30 year time horizons. There are a number of reasons for this. Alternative development sites are extremely limited for quarries, power plants, steel mills, chemical plants, petroleum refineries, and paper mills. In many instances production is geographically limited, as is the case with stone, wood products, and coal.

Consuming plants may also require specifications unique to a particular ORV resource. This is particularly true with respect to the requirements of some utility plants for certain grades of coal for their boilers, chemical properties of limestone for their flue-gas desulfurization units, and adequate supplies of cooling water from the river. Finally, transportation options are often extremely limited. Large machines and fabrications, like electricity generators, often can move no other way than by water, and high volume bulk commodity shipments can be moved in a less disruptive fashion past most major urban concentrations than through them. Limited alternatives for locating new plants, substituting products from other areas, and arranging alternative transportation act to make long run demands for waterway service in the ORV relatively stable (U. S. Army Corps of Engineers (2), April, 2000).

The study area encompasses a broad spectrum of industrial activities. Brief profiles of industries most closely associated with direct utilization of river transportation are presented below.

7.9.3.1.1 Coal Utilities and Related Activities

Abundant coal reserves in states bordering the Ohio River are one of the primary cornerstones of past economic development in the ORV and provide the overwhelming majority of fuel for electric generating capacity in those states today. Coal provided 57% to 98% of total electric generating capacity in 1997 to the six states bordering the study area (U. S. Energy Information Administration, 2001). Development of affordable, reliable coal transport was one of the primary motivations for initial and subsequent development of Ohio River navigation improvements. Coal accounts for over 55% of all commodities shipped on the ORS, and this coal accounts for about 14% of consumption by the electric generating industry nationwide (U. S. Army Corps of Engineers (2), April, 2000).

The concentration of coal-fired power plants in conjunction with the high sulfur content of much of the region's coal results in the number one air pollution source in the region for SO_2, NOx, and PM. Indeed, the sheer quantity of these emissions tends to overshadow the impacts of other sources in the region. Since 1980, the six states bordering the Ohio River have ranked among the top seven or eight nationwide sources of SO_2 from coal-fired utilities. NOx emissions from these sources contribute to local concentrations of O_3; NOx and SO_2 are the key contributors to acid rain impacts throughout the midwest and northeast, and into southeastern Canada SO_2 is a primary contributor to regional haze/visibility and fine particulate impacts (U. S. Environmental Protection Agency, 2001a,b, Nov.,1999b).

7.9.3.1.2 Other Industries Dependent on River Navigation

Regional industries with strong ties to Ohio River navigation can be classified into two broad air quality groups. The first group includes primarily PM sources such as sand and gravel mining, quarrying, and gypsum processing. The second group includes industrial operations that emit a broader spectrum of air pollutants; refineries, chemical plants, steel mills, coke ovens, and related sources. All of these industrial sources are required to obtain air pollution permits and must meet specific emission standards as specified in those permits. Permit requirements are established on the basis of CAA regulations that establish industry standards, control technology feasibility, and the address the sensitivity of impacted areas. Industry standards help to establish regulation of equivalent industrial processes while the control capabilities of available technology help to define what is achievable. Industrial sources located in nonattainment areas, emitting significant quantities of a priority pollutant, or otherwise impacting a sensitive resource may be required to meet more stringent emission control standards. New source performance standards, applicable to new or extensively renovated facilities, require use of the most advanced available controls; helping to integrate reduced air emissions into the process of industrial modernization.

7.9.4 Reasonably Foreseeable Future Actions

7.9.4.1 Future Air Quality in the ORV

USEPA and the states are currently implementing major initiatives to reduce NOx emissions from heavy-duty diesel vehicles, coal-fired power plants, and other industrial sources. The vehicle initiatives will have nationwide impacts through reduction of emissions from highway trucks and buses, diesel locomotives, construction equipment, commercial marine engines, and other classifications of diesel combustion sources. In addition to the acid rain program, which establishes national NOx emission standards, three regional programs are in effect that will further reduce NOx emissions from power plants and other industrial sources in the midwest and northeast. In this region, NOx and VOC are the principal contributors for local ozone problems, NOx and SO_2 are principal contributors for acid rain, and NOx is an additional contributor to the formation of $PM_{2.5}$.

Regulation of utility emissions under national and regional cap and trade allowance programs is reducing present emissions and will impose a ceiling on any future increases. These programs are intended to establish a sustainable balance – enough emissions to allow sustained viability of the coal electric industry, trading of emission allowances to

promote cost effective control of emissions, and enough reductions to allow recovery of impacted populations and resources (USEPA, 2001a, b, and August, 2000).

While emissions from coal-fired utilities can be expected to decline and stabilize during the early years of the study period, the cap and trade regulations may contribute to a number of changes in the transport of coal. For the short term at least, net tonnage of coal transport on the ORS appears to have leveled off. Virtually all expansion of electric utility capacity since 1996 has come from natural gas and no plans for expansion of coal facilities during the next several years have been formally recorded. There is a general expectation that some expansion of coal capacity will eventually occur, however there may be a 10 or 15-year lag relative to coal transport projections previously prepared for ORMSS (U. S. Army Corps of Engineers (3), April, 2000). There is some expert agreement that expansion of coal capacity, when it eventually occurs, will be centered on existing coal-fired plants. These plants already occupy the best sites and would likely face less complicated permitting than would new sites.

Although coal shipments have largely leveled off, distribution patterns have changed and are likely to continue. There has been a significant increase in quantities of low sulfur western coal being shipped up the Ohio River and compensating decreases of higher sulfur coal from mines in the ORV. On a smaller scale, installation of SO_2 scrubber technology is contributing to shipments of limestone to the plants and gypsum (a marketable by-product of desulfurization) from the plants (U. S. Army Corps of Engineers (3), April, 2000). Finally, the long-term relationship between coal consumption and energy production could fluctuate up or down. Western coal tends to have lower energy content, requiring more coal per unit of electricity produced. On the other hand, advances in coal combustion technology could result in a decrease in use of western coal and an increase in use of coal from the ORV over the long term.

As previously noted, VOCs combine with NOx to form O_3. Substantial progress has already been made in the control of VOCs and future gains will be more difficult to achieve. However, new VOC standards are being implemented for recreational boats and other classifications of gasoline combustion engines.

For the Ohio River region, sulfates are the primary precursor to the formation of $PM_{2.5}$, accounting for over 50% of particulate composition at monitoring stations east of the Mississippi River. NOx is an important secondary precursor. The acid rain program, regional NOx programs, and NOx vehicle initiatives are the primary activities that will contribute to reduced $PM_{2.5}$ emissions in the ORV.

National initiatives to control emissions of NOx, VOC, $PM_{2.5}$, and sulfates from SO_2 will reinforce the local and regional programs of the nonattainment areas. Additionally, state and national programs provide a broad spectrum of assistance in the form of training, equipment grant/loans, shared data and information, and approaches to implementing new programs (USEPA, Aug. 2000). More detailed descriptions of these upcoming air pollution control programs are presented in Section 7-13 to this chapter.

In addition to the scheduled programs described in Section 7-13, research and policy analysis continues to address other air quality issues that may be incorporated in future regulatory initiatives. The issue of mercury emissions from coal fired power plants and other sources is prominent in current discussions. USEPA is researching alternative

regulatory approaches and has issued a recommended approach. Eventual implementation of mercury regulations would have potentially significant influences on barge transportation of coal within the ORV. Implications of these potential regulations have been addressed in the Corp's Traffic Demand Forecasts (U. S. Army Corps of Engineers (1), Feb, 2004).

7.9.4.2 Economic and Population Growth

Continued growth of the economy, vehicular travel, and population will erode some of the anticipated future air quality progress. Between 1970 and 1999, the national population grew by about 33%, while total vehicle miles traveled increased by 140%. This dramatic growth of vehicular travel negated much of the progress in controlling pollution from mobile sources. Growth during this 30-year period is attributable to traditional non-drivers becoming full-time drivers and development of the transportation infrastructure that facilitated the suburban commuting lifestyle that is so prevalent today throughout much of the ORV.

During the past 30 years, Gross Domestic Product (GDP) also grew dramatically faster than the population. With unlimited opportunities for continued technological advancements, improved productivity, and growth of trade and service sectors, it is not inconceivable that similarly dramatic growth is possible for the future. However, the growth profile for the future includes a mixture of activities reflecting a shift from a manufacturing economy to a service and information based economy that would produce comparatively less air pollution than associated with past growth. Additionally, the impact of growth in traditionally polluting sectors is mitigated somewhat by the fact that new industrial infrastructure with designed-in pollution control tends to be much cleaner than previous facilities with add-on controls.

Within the states bordering the ORV, it seems likely that coal will continue to be the primary source of electric power generation. The region possesses massive supplies of coal, no alternative power source shows any indication of supplying a significant share of the net load, and the developed infrastructure of mines, coal transport, power plants, and transmission system constitutes one of the most cost efficient power production systems in the nation. The cap and trade system of controlling emissions allows room for significant growth with existing control technology and incentives to achieve additional growth through plant renovation and modernization.

7.9.4.3 Towboat Traffic Projections

The Navigation Data Center based in the Huntington District, monitors waterborne commerce throughout the ORS. The Center collects waterborne commerce and lock performance statistics and performs shipper/consumer surveys. Analysis of this information is used to forecast trends in system traffic demands and to forecast individual lock performance. Results of such analyses are used to determine which facilities are most in need of improvement and to evaluate the feasibility of navigation modernization proposals.

The most recent analyses and forecasts of traffic demand were completed in 2005 for the ORMSS SIP. These analyses addressed five separate scenarios and projected growth rates between 0.50 and 1.03 per cent per year for the Ohio River mainstem. Three

of the scenarios recognized the impacts of potential future air pollution regulations; including the existing program of NAAQS, proposed 'clear skies' amendments to the NAAQS, and 'clear skies' minus proposed new limits for mercury emissions. The forecasts are discussed in greater detail in Chapter 10, Transportation.

7.10 CUMULATIVE EFFECTS: EMISSIONS FROM LOCK AND DAM MAINTENANCE

7.10.1 Emissions from Barge Delays

Emission factors for marine diesel engines are expressed as pollutants emitted per ton of fuel burned (USEPA, September 1999b). Project documentation for construction of lock extensions at Myers and Greenup L&D included estimates of the total quantity of diesel fuel that would be burned as a result of delays during maintenance closures, under the Without Project scenario, over the 60-year span from 2000 to 2070 (U. S. Army Corps of Engineers (1), April, 2000). In these estimates, fuel consumption due to queuing at Greenup was predicted to be more than twice the amount predicted for Myers, due in part to the history of longer and more frequent maintenance closures at Greenup. Using predicted closures at Myers as the case representing a typical lock and dam on the Ohio River, total emissions due to maintenance related queuing were calculated as a function of traffic volume for the entire Ohio River L&D system. These projected emissions are reported in **Table 7-8**.

TABLE 7-8
Total Emissions from Maintenance Delays 2000-2070

L&D Project	1998 Tonnage	Diesel[4] Burned	NOx (tons)	PM (tons)	VOC (tons)	CO (tons)
L&D 53[1]	97,695	-	-	-	-	-
L&D 52[1]	97,695	-	-	-	-	-
Smithland[2]	84,606	-	-	-	-	-
Myers	74,151	7.7	1,892	39.6	79.8	245.4
Newburgh	64,131	6.7	1,637	34.2	69.0	212.4
Cannelton	54,386	5.6	1,388	29.4	58.8	180.0
McAlpine[3]	52,867	-	-	-	-	-
Markland	56,119	5.8	1,432	30.0	60.6	186.0
Meldahl	63,739	6.6	1,627	34.2	69.0	211.2
Greenup	70,638	18.0	4,424	93.0	187.2	574.2
Byrd	57,855	6.0	1,477	31.2	62.4	192.0
Racine	40,517	4.2	1,034	21.6	43.8	134.4
Bellville	48,688	5.1	1,243	26.4	52.8	161.4
Willow Is.	44,766	4.6	1,142	24.0	48.0	148.2
Hannibal	47,627	4.9	1,216	25.8	51.6	157.8
Pike Is.	43,027	4.5	1,098	23.4	46.2	142.8
New Cumberland	35,425	3.7	904	19.2	38.4	117.6
Montgomery	26,866	2.8	686	14.4	28.8	88.8
Dashields	24,563	2.6	627	13.2	26.4	81.6
Emsworth	23,153	2.4	591	12.6	25.2	76.8

L&D Project	1998 Tonnage	Diesel[4] Burned	NOx (tons)	PM (tons)	VOC (tons)	CO (tons)
Ohio River Total		91.2	22,418	472.2	948.0	2,910.6
Notes:						
1 L&D52 & L&D53 to be replaced by Olmsted L&D, with dual 1200' locks. No queuing emissions due to chamber closures.						
2 Smithland has dual 1200' locks. No queuing emissions due to chamber closures.						
3 McAlpine, under construction, will have dual 1200' locks. No queuing emissions due to chamber closures.						
4 Diesel, millions of gallons burned during closure delays over 60-year study period.						
Source: U. S. Army Corps of Engineers (1, 3), April 2000 and U. S. Environmental Protection Agency, September 1999b						

7.10.2 Emissions from Construction Activity

In addition to the queuing emissions described above, air emissions from maintenance and repair construction activities would also occur. For most repairs, construction site and equipment emissions will be smaller, in proportion to the reduced scale of the repair activity compared to those of lock extensions. Major repair events to upgrade or overhaul aging lock systems would be comparable to construction emissions that would occur as a result of a lock extension from 600' to 1200'. Total air emissions attributable to construction activities were calculated for proposed lock improvements at J. T. Myers and Greenup and reported in the Environmental Impact Statement (EIS) for that project (U. S. Army Corps of Engineers(1), April, 2000). Because the two projects are so similar in scope, the estimated air emissions are the same. Estimated construction emissions for one project are presented in **Table 7-9**.

TABLE 7-9
Estimated Air Emissions from Typical 600' to 1200' Lock Extension

Emissions in Tons (numbers rounded)				
600' Lock Extension	**VOC (tons)**	**CO (tons)**	**NOx (tons)**	**PM (tons)**
Year 1	02	12	13	1
Year 2	11	66	74	8
Year 3	01	03	3	<1
Total	**14**	**80**	**91**	**10**
Source: U. S. Army Corps of Engineers (1), April, 2000				

Average annual air emissions attributable to routine and major repair events can be roughly estimated. If major repair events occur about once every ten years, it can be assumed that average annual emissions from construction activity are about 10 per cent of the total estimated for a 600' to 1200' lock extension. This would result in an estimate of 9.1 tons per year of NOx emissions due to construction activities at each lock and dam project on the Ohio River.

7.10.3 Cumulative Emissions from Lock and Dam Maintenance

Air emissions attributable to construction activity and queuing due to lock and dam maintenance activity can be displayed as annual emissions for the entire Ohio River

navigation system and compared to previous estimates for Tows Underway (from **Table 7-5**) and emission inventories for all Marine Emissions and for All Sources (from **Table 7-4**). These comparisons, presented in **Table 7-10**, place air emissions from lock and dam maintenance activity in context with the larger emission categories.

TABLE 7-10
Annual System-Wide Emissions

	NOx (tons/yr)	PM (tons/yr)	HC (tons/yr)	CO (tons/yr)
Maintenance Delays	373.6	7.9	15.8	48.5
Construction Emissions	172.9	19	26.6	152.0
Total Maintenance and Construction	546.5	26.9	42.4	200.5
Total Emissions for Tows Underway	26,739	1,273	637	3,183
Total Marine Vessel Emissions	59,430	3,216		6,246
Emissions from All Sources	1,253,044	336,708		2,557,184

7.11 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

One of the seven environmental operating principles of the Corps is to strive to achieve Environmental Sustainability (ES). ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation, and maintenance to improve the quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of CEs can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An Analysis of ES (AES) has been and is being used in several other programmatic studies by the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps:

(1) identification of "common effects" on air quality parameters from the High and Medium importance RFFA as delineated in the pertinent RFFA matrix;
(2) selection of sustainability indicators for air quality, and their grouping, as appropriate; and
(3) consideration of the "connections" between the common effects and the indicator groups.

The output of the AES consists of a qualitative (descriptive) discussion of the "connections", with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions – what is the current ES for air quality, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable – the composite conditions for the selected indicators of ES for air quality do not reflect conditions that would facilitate attainment of acceptable standards or would not maintain existing standards in concert with collective impacts of proposed activities.
- Marginally sustainable – the composite conditions for the selected indicators of ES are such that the attainment of acceptable living conditions and quality of life is accomplished for the majority, but not all, of the potentially affected populations. However, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of air quality for the Ohio River).
- Sustainable – the composite conditions for the selected indicators of ES are such that the attainment of acceptable living conditions and quality of life is accomplished for essentially all of the potentially affected populations in the ORV, and such standards are maintained in concert with foreseeable future activity. Further, the conditions of the indicators exceed regulatory thresholds and various governmental programs are in place to respond to any potential erosion of ambient Air Quality.

Common effects of multiple actions have been previously discussed in the sections entitled "Interactions with Other VECs" and "Relevant Actions Affecting Air Quality".

Indicators or groups of indicators of air quality were identified earlier in the section entitled "Indicators of Sustainability", and relevant information on them have been presented in the section entitled "Past to Current Baseline Conditions". For the purposes of this analysis, the above indicators are grouped into three tiers for the conduction of the AES. The three tiers are as follows:

- first tier – "scientific measures of air quality factors"
  (1) National system for monitoring pollutant releases to the atmosphere, including industry reporting requirements, regulatory inspections and measurement of pollution sources, and state/federal programs to calculate annual emission inventories from all sources.
  (2) National system to monitor ambient air quality.

- second tier – "composite measures of air quality factors"
  (1) Analyses to confirm that pollutant source reductions are contributing to improved ambient air quality.

- third tier – "composite indicators of air quality sustainability"; this includes measures developed from multiple indicators
  (1) Attainment of ambient air quality standards.
  (2) Ongoing health risk assessments to determine whether attainment of existing air quality standards adequately protects human health and other resource values.

7.12 CONCLUSIONS REGARDING CUMULATIVE AIR QUALITY EFFECTS

7.12.1 Mitigation and Monitoring of Cumulative Air Quality Effects

Regarding cumulative air quality effects of the ORMSS, no significant concerns have been identified. This conclusion is based upon a combination of considerations related to: (1) the small contributions of the waterway navigation system to annual emission inventories in the study area and (2) the existence of the CAA and its comprehensive requirements for air pollutant source control measures, pollutant caps, and the attainment of ambient air quality standards. Further, additional reductions in NO_x emissions from marine diesel engines are planned by the USEPA. Accordingly, no unique mitigation requirements are envisioned for the waterway navigation system other than conventional practices used to reduce pollutant emissions during construction. Finally, improvements to the system will reduce barge queuing and associated incremental emissions.

Air quality monitoring is currently conducted in several major cities in the study area. As a result of the lack of significant cumulative air quality concerns and the existing monitoring programs, no additional monitoring related to the waterway navigation system is required.

7.12.2 Summary of Findings

Based upon the analyses included herein, the following findings have been identified:

The spatial boundaries for the study include the corridor along the mainstem of the Ohio River. Regarding emission inventory information, the counties along both sides of the River were included. Finally, long-range transport of air pollutant was considered but not addressed in detail due to the small contributions of the navigation system to the county-based emission inventory.

The temporal boundaries for the study ranged from 1920 to 2070. The future date (2070) was selected based on the Corps' planning horizon for the development of a system-wide investment strategy for the ORMSS. The beginning date (1920) reflects the approximate initiation date for the Corps' modernization program for locks and dams on the Ohio River. However, from a pragmatic standpoint based on the availability of air quality data and the existence of a regulatory program by USEPA, the year 1970 better reflects the utilized historical baseline.

Numerous sources of NO_x, CO, SO_2, PM, and VOC emissions exist within the study area. The sources are associated with direct actions of the Corps (e.g., construction of lock chamber extensions; lock maintenance, repair, and rehabilitation; operation of the system; and dam rehabilitation); direct actions by others (e.g., commercial navigation activities; barge traffic waiting to pass through locks; and barge loading/unloading and other intermodal operations); and indirect actions by others (e.g., industrial plants, coal utilities, urban and rural transportation, and commercial sand and gravel operations).

Air quality management programs were initiated in 1970 with the passage of the CAA. Numerous amendments have occurred since then, thus leading to the current comprehensive program coordinated by USEPA and administered by state agencies in the six states located along the Ohio River mainstem. The current program includes ambient air quality standards, emission standards for stationary sources, emission standards for mobile sources (cars, trucks, etc.), allowance trading for SO_x emissions from power plants, monitoring requirements, and many other features. The current program and the anticipated more stringent requirements in the near-term for related pollutant emission actions in the study area indicate that air quality is subject to numerous controls and regulatory measures focused on reducing undesirable effects on human health.

Using 2004 data, comparisons of current air quality levels with the pertinent ambient air quality standards have revealed that 10 counties in 4 states continue to be designated as non-attainment for either ozone (based on the 1-hour standard), PM_{10}, or SO_2. The counties in Illinois are in compliance with the standards. The new 8-hour standard for O_3 has resulted in designation of 37 counties in 5 states. All of the non-attainment counties are within or adjacent to standard metropolitan statistical areas for major cities within the Ohio River corridor.

The 1999 emission inventories for counties bordering the Ohio River were used to examine the contributions of various pollutant source categories, including direct actions by the Corps and others related to the waterway navigation system. It was found that construction, operation and maintenance, and rehabilitation activities of the Corps contribute considerably less than 1% of the annual emissions inventories for NO_x, CO, and PM. Barge towboats contribute 2.1% of the annual inventory for NO_x, 0.38% for PM and 0.12% for CO. Emissions from towboats in queue at locks, although they are small on a comparative basis to other sources in the study area, can be further reduced:

- Through improvements to auxiliary locks in the system
- Through improved moorage at frequent queuing points in the system.

No significant cumulative air quality effects have been identified. This conclusion is based upon the following considerations: (1) the direct actions associated with the waterway navigation system exhibit only minor contributions to the annual emission inventories; (2) barge towboats contribute 2.1% of the annual NO_x inventory, and new regulations for marine diesel engines should reduce this contribution; and (3) the CAA and the associated ambient air quality standards, source control regulations, and trading programs provide an in-place management structure for both individual and cumulative air quality effects.

Because the cumulative air quality effects are not significant, no special modifications or mitigation measures would be required under either the "With Project scenario" or the "Without Project scenario". This is based on the valid assumption that environmentally responsible practices would be used to reduce the NO_x, CO, VOC, and PM_{10} emissions during various construction, maintenance, repair, and rehabilitation activities. Further, because an extensive air quality monitoring network already exists in the study area, no special monitoring for cumulative air quality effects will be required.

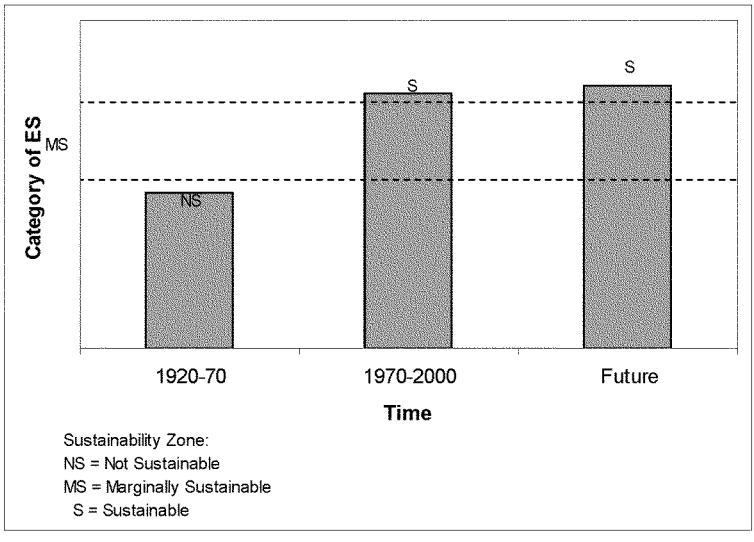
Based upon the above-described actions and effects, the tiers of indicators, and the ES categories, the ES of air quality for the ORV can be characterized and depicted in **Figure 3** as follows:

- In the time period prior to 1920, and continuing up to about 1970, the air quality of the ORV was in a degraded state and thus classified as "not sustainable" due to largely untreated and uncontrolled point and nonpoint pollutant discharges from coal fired power plants, other types of industries, and vehicular sources.

- Due the requirements of the Federal CAA of 1970 and subsequent amendments, the air quality in the region has shown a steady improvement in recent decades; thus it is currently in a "sustainable" category.

- Regarding the future, it is expected that air quality in the ORV will further improve as a result of the continuation of source control and other pollution reduction programs; thus, it will be maintained in a "sustainable" condition. However, this characterization should not bring complacency; rather, vigilant efforts are still needed to continue effective air quality monitoring and management efforts. Such efforts are reflected in the recent implementation of more stringent standards for O_3 and PM, ongoing efforts to establish effective limits for mercury, and to continue analysis of the need to control other types of emissions.

FIGURE 7-3
Environmental Sustainability of Air Quality for the Ohio River Valley



7.13 SUPPLEMENT – FUTURE IMPACTS OF AIR QUALITY REGULATORY PROGRAMS

This section provides information on recent developments and proposed regulatory programs for several categories of air pollutant sources.

7.13.1 NOx Vehicle Initiatives

7.13.1.1 Heavy-Duty Diesel and Gasoline Engines.

After several years of working with fuel refineries and the manufacturers of heavy duty diesel and gasoline engines, USEPA issued final rules in July and December, 2000 that will eventually reduce emissions from these vehicles by over 90%. The first phase takes effect for all diesel engines over 8,500 pounds manufactured in 2004 and for heavy-duty gasoline engines in the 2005 model year. The sulfur content of highway diesel fuel will be reduced by 97% in 2006 and vehicles designed to utilize high-efficiency catalytic exhaust systems will be required beginning in model year 2007. Total phase-in of the program will extend to 2030, when the current heavy-duty vehicle fleet will have been completely replaced by newer, emission compliant vehicles.

Heavy-duty trucks and buses currently account for about one-third of NOx emissions and one-quarter of PM emissions from all mobile sources. NOx emissions will be reduced by 95% from current levels, resulting in net reductions of 2.6 million tons per year (tpy) by 2030. PM emissions will be reduced by 109,000 tpy (a 90% reduction) and VOC by about 115,000 tpy (U. S. Environmental Protection Agency, December 2000a&b).

7.13.1.2 Nonroad Diesel Engines.

This category of emission sources includes construction equipment such as bulldozers, road graders, excavators, and portable generators as well as farm tractors and logging equipment. These sources account for about 10% of total NOx emissions and frequently contribute a larger percentage in communities with air quality problems. Tier I standards for new engines over 50 hp were phased in from 1996-2000 and for engines under 50 hp from 1999-2000. More stringent standards for all engine sizes went in effect from 2001 through 2006 and a third tier of standards will be applied to engines over 50 hp from 2006-2008. By 2010 it is expected that these controls will reduce NOx emissions from this source group by 1 million tpy, with larger reductions in later years as older equipment is replaced with newer, cleaner burning equipment (U. S. Environmental Protection Agency, August 1998 and Nov. 2000).

7.13.1.3 Locomotives.

The final rule for locomotives was issued in December 1997 and began to take effect in 2000. From this point forward, all new and remanufactured locomotives must meet applicable emission standards, which increased in 2002 (Tier I) and again in 2005 (Tier II). Locomotives have an average service life of 40 years or more and are remanufactured every 4 to 8 years. The program is expected to reduce NOx emissions by 267,000 tpy in 2010 and 650,000 tpy in 2040 (a 60% reduction). Prior to these regulations, locomotives accounted for over 10% of NOx emissions from mobile sources, or almost 5% of total nationwide NOx emissions. PM reductions will exceed 12,000 tpy by 2040, a 46% reduction from baseline levels and more than 1% of mobile source emissions (U. S. Environmental Protection Agency, Dec. 1997).

7.13.1.4 Commercial Marine Diesel Engines.

This source group includes engines used for propulsion and auxiliary power on commercial vessels in a variety of marine applications, including tugboats, towboats, and dredgers. A study of air emissions from nonroad engines, conducted by USEPA in 1990, found that commercial marine diesel engines accounted for about 4.4% of total mobile source NOx emissions and about 1% of PM emissions. The study also concluded that NOx and PM emissions from marine engines were likely to be concentrated around commercial ports and heavily populated coasts. In a final rule issued November 1999, emission standards are applicable to new engines manufactured between 2004 and 2007, depending on the size of the engine. When the program is fully phased-in by 2030, these standards are expected to result in a 24% reduction of NOx emissions and a 12% reduction of PM emissions from this source (U. S. Environmental Protection Agency, Nov. 1999b).

7.13.2 VOC Vehicle Initiatives

7.13.2.1 Gasoline Marine Engines.

USEPA issued the gasoline marine final rule in August 1996, applicable to outboard engines and gasoline engines used in personal watercraft and jet boat applications. The new standards did not apply to sterndrive and inboard engines because of the inherently clean technology already utilized by these engines. USEPA's 1990 study of nonroad engines found that recreational marine engines contributed an average of about 3.3% of total VOC emissions, and noted that the percent contribution could be expected to be significantly higher wherever watercraft were concentrated in proximity to population centers. Since VOCs interact with NOx to form ground level O_3, a concentration of both sources in proximity to each other might magnify this effect even more.

Emission reduction goals are to be reached through the phased introduction of new generation engines that offer improved performance and fuel economy and eliminate fuel/oil mixing, in addition to achieving a 75% reduction of VOC emissions. These new generation engines were expected to be available as early as 1997 and are expected to completely replace the existing generation of engines by about 2025 (U. S. Environmental Protection Agency, Aug. 1996).

7.13.3. NOx Power Plant/Industrial Source Programs

7.13.3.1 Acid Rain Program.

Electric utilities generate about 30% of the nationwide total of around 23 million tpy NOx emissions. These emissions have remained relatively stable since the mid-80's. Although cleaner technologies have been introduced in many industrial settings, these reduced emissions have been offset by growth of the electricity generation and vehicle use source categories. Under the national acid rain program, NOx emissions were to be reduced about 400,000 tpy between 1996 and 1999 (Phase I) and by a total of 2 million tpy between 2000 and 2007 (Phase II). These goals are being pursued by designating a NOx emission limit of between 0.40 and 0.86 lbs/mmBtu, depending on the boiler type at the source. Among facilities participating in Phase I of the NOx program, average

emission rates have decreased by 42% since 1996 (U. S. Environmental Protection Agency, Nov. 1999a).

7.13.3.2 Regional NOx Programs.

Within the ORV area, three regional programs to further reduce NOx emissions are being implemented. These include the Ozone Transportation Commission (OTC), the NOx SIP call, and the Federal NOx Budget Trading Program (Sec. 126). All of these programs are intended to reduce ground level ozone and the applicable emission limits that apply to a "summer season" period of compliance. All of the programs apply a cap and trade program internally and some opportunities exist for trading among programs (U. S. Environmental Protection Agency, 2001b).

The OTC applies to a specific group of "other" industrial sources in 12 northeastern states, including Pennsylvania. From a 1990 baseline of 490,000 tpy, these sources are utilizing a cap & trade program that was to reduce emissions to 219,000 tpy by 1999 and to 143,000 tpy by 2003. After 2003, control levels are similar to the Sec. 126 program and trading among programs may become feasible at that time.

The NOx SIP call applies to 22 midwest and northeast states that include all six of the ORV states. The initial compliance year for this program is 2004 and as yet not all states have finalized their lists of participating sources, baseline emissions, and caps. States have an option to participate in the Federal NOx budget trading program, which would allow free trading of emissions credits among participating sources.

The Sec. 126 final action is the result of a settlement of petition to USEPA from four northeastern states seeking to reduce O_3 pollution through reductions in NOx emissions in other states. The program requires 392 facilities in 12 states and the District of Columbia to reduce annual NOx emissions through participation in a cap-and-trade program. All ORV states except Illinois are included in this program, which regulates all large electric utilities and large industrial boilers in the area. Fossil fuel fired boilers or combustion turbines with rated output of greater than 25 MW or maximum rated heat input capacity of greater than 250 mmBtu/hr are included.

The emissions cap established by the Sec. 126 final action picks up where the acid rain program for NOx leaves off. Annual emissions from the 392 facilities will total 510,000 tons less than the year 2007 levels established by the national program. Additionally, all utility and industrial NOx emissions in the region will be capped; new plants will be issued initial NOx "allowances" but will be required to operate within the regional emissions limit. Emission allowances for 2003-2007 were issued in December 1999, with reserve allowances for new sources and incentives for sources that make early reductions in 2001 or 2002.

7.13.3.3 Reduction of SO_2 Emissions

Reduction of SO_2 emissions under the acid rain program is focused on reversing the trend of acidification of lakes, streams, and forests nationwide and associated impacts on visibility, respiratory health, agricultural productivity, and degradation of monuments and buildings. SO_2 is also an important precursor of $PM_{2.5}$, especially in the east, and control of the former will help lessen the human health impacts of the latter. The combustion of

coal for electric power is the principal source of SO_2 emissions; utilities account for about 67% of total annual discharges. The high sulfur content of midwestern coal results in an overwhelming concentration of sources within or adjacent to this region. Since 1980, the six states bordering the Ohio River have ranked among the top seven or eight nationwide sources of SO_2 from coal-fired utilities.

The program to reduce SO_2 emissions began in 1995 with emission reductions from large electric power generators. This group achieved reductions of almost 5 million tpy, or about 30% below allowable emission levels in advance of future limits. Phase II of the program began in 2000, regulating a greater number of smaller plants and requiring further reductions from larger plants. Full compliance by 2010 will result in attainment of the emissions cap of 8.95 million tpy; a reduction of almost one-half from industry wide emissions in 1980 (U. S. Environmental Protection Agency, 2001a and Nov. 1999a).

7.13.4 New standards for O_3 and $PM_{2.5}$

Better understanding of the health impacts of ozone and PM led to the establishment of the new standards. Achieving these health benefits will require greater effort and expense for programs in existing nonattainment areas as well as new programs in areas that were previously designated as attainment. Locally implemented efforts can include requiring the use of cleaner burning gasoline, vehicle inspections, and more stringent enforcement of existing regulatory authority. Some industrial sources may become subject to tighter emission standards in nonattainment areas while area sources such as dry cleaners may benefit from incentive programs to modernize their equipment. Although states retain their individual jurisdictions, it is important to establish communication and program coordination wherever nonattainment areas cross state boundaries, which is likely to apply to virtually all nonattainment areas in the ORV.

There is a direct relationship between weather conditions and the local buildup of O_3. Accumulations of fine particulate are also likely to be dependent on weather conditions. Ambient monitoring resources can be utilized to predict the occurrence of potential exceedances several days in advance. As a result, it is important that nonattainment communities develop and utilize strategies and authorities to restrict pollutant-contributing activities. These can range from asking people not to mow their lawns to requiring a major industrial source to temporarily cease or restrict operations. The ability to constrain emissions for even a day or two can make the difference between passing or failing an air quality standard.

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Chapter 8
HEALTH AND SAFETY

8.1 TABLE OF CONTENTS

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8.2 DEFINITION OF RIVER-RELATED HEALTH AND SAFETY IMPACTS

Health and Safety (H&S) considerations are primarily related to human communities rather than resources and ecosystems. However, some H&S measures may impact resources or ecosystems. The H&S Valued Environmental Component (VEC) consists of:

Worker health and safety – this refers to construction workers and workers related to lock and dam (L&D) operation, assemblage/ disassemblage of barges in tow,

operation of tows and helper boats, and barge loading/unloading. Concerns relate to effects on worker H&S from construction accidents (or accidents during maintenance, repair, or rehabilitation of navigation system components), routine system operations, barge accidents, and barge loading/unloading activities.

General population health – this refers to chemical or bacteriological exposures to the human population using the Ohio River as a water supply, or using the river for body contact recreation (swimming and/or water skiing). Exposures can occur from chemical or other spills into the river or its tributaries from industries and barges, from releases of contaminants from industrial or municipal sediments in the river, from releases from nearby hazardous waste sites, and/or from accidents (ruptures) related to pipelines crossing the river. Such exposures can occur from ingestion of river water prior to or following treatment, from ingestion of contaminated fish or aquatic species, and from dermal exposure to the water.

Recreational boater safety – this refers to accidents experienced by those persons engaged in recreational boating on the Ohio River.

Noise refers to the ambient sounds audible in an area or environment, comprised of sounds from varying distances. Both workers and the general population may be subject to noise impacts. Noise impacts may originate from temporary sources (e.g., a construction site) or more permanent activities such as airports and highways.

8.3 OBJECTIVES AND SCOPE OF THE HEALTH AND SAFETY STUDY

8.3.1 Objectives

This chapter assesses the system-wide cumulative health and safety impacts of all likely major navigation improvements along the mainstem of the Ohio River from 2000 - 2070. Health and safety impacts that are directly or indirectly attributable to modernization of the navigation system are evaluated in concert with impacts from other past, present, and Reasonably Foreseeable Future Actions (RFFAs) by the US Army Corps of Engineers (Corps) and others.

Assessment of past and present actions and current conditions is the basis for identifying and interpreting the potential impacts of RFFA. These future actions include the major navigation improvements identified in this study, other routine or potential actions by the Corps, projected actions by other federal, state, or local agencies, actions by non-governmental entities, and predictions of general economic expansion and development.

At the beginning of the study process, noise issues were investigated as a separate VEC from the Health and Safety VEC. Noise and H&S were presented as separate VECs at public scoping meetings and in the analysis of RFFAs. The results of these efforts led to the conclusion that noise issues would be more effectively discussed as a part of the general Health and Safety VEC, rather than as a separate VEC.

The results of the Cumulative Effects Assessment (CEA) are intended to contribute to two topics of subsequent public concern: (1) whether the impacts of the RFFAs constitute acceptable outcomes for the affected resources and (2) how the proposed navigation improvements contribute to those outcomes.

8.3.2 Geographic Scope

The geographic focus for health and safety impacts includes those areas most directly impacted by presence of the navigation system. Other potential health and safety impacts include construction site activities at locks and dams, boating accidents, spills, operational practices associated with commercial navigation, other boating accidents, and impacts from other sources. Potential impacts would mostly occur on the water surface or adjacent banks, but some of the other potential sources of such impacts are located away from the banks such as floodplains. These potential sources include facilities that process, transfer, or store oils and fuels; industrial facilities that use other toxic or hazardous materials; construction sites such as bridges or riverfront developments; contaminated sites that may leach pollutants; other municipal and industrial point sources, and contaminated surface runoff. To account for such sources, the geographic focus for health and safety impacts is defined as the river surface plus the land surface for one mile from either bank. Point and nonpoint sources such as combined sewer system overflows (CSO) or stormwater runoff that do not fit this geographic scope are also recognized.

8.3.3 Time Frame

The established time frame for this project is 1920 to 2070. The earlier date approximates the initiation of modern Corps L&D construction activities on the Ohio River. The latter date approximates the end of the 60-year planning horizon encompassed by the Ohio River Main Stem System Study (ORMSS).

8.4 ISSUES FROM SCOPING

A series of 12 public scoping meetings was held during Summer 2001 in communities along the Ohio River. The meetings created opportunities for the public, state and local agency representatives, and other interested groups to provide input on potential issues related to the CEA. Meeting attendees could provide input through comments during the question and answer sessions, completion of questionnaires, or direct written comments. Direct mailings and advertisements of the meetings also provided opportunities for public comments via questionnaires, letters, or email. More detailed discussions of the scoping meetings are presented in this report in Exhibits A and B.

A total of 185 people attended the meetings and over 200 verbal comments were recorded from the question and answer sessions. These comments accounted for the large majority of input. Additional comments were obtained from 19 questionnaires and several letters that were submitted.

Public H&S was a significant focus of the meetings. Comments that directly and indirectly addressed H&S are presented in **Table 8-1**. Additionally, questionnaire respondents were asked to assign an importance number to each of the 12 VECs identified in the CEA. Although it is important not to draw too strong a conclusion from only 19 completed questionnaires, it is worth noting that the Health & Safety VEC (including hazardous waste sites and chemical spills) received the highest score of 2.8 out of a possible 3.0. Noise, listed as a separate VEC on this questionnaire, received the lowest ranking among the 12 VECs.

TABLE 8-1
Comments from Public Scoping Meetings

Direct Comments on Health and Safety Issues	Total
Failure of barges to stay in designated shipping lanes	2
Increased spills and accidents potentially affecting aquatic life and impairing water quality	1
Safety concerns related to uneven arrangement of barges on towboats	1
Challenges to water quality presented by CSOs and SSOs	2
High levels of mercury, arsenic, fecal coliform bacteria and agri-chemicals in surface water	1
Importance of continued water quality improvements as a high priority	1
Need to protect public groundwater supplies	1
Impaired water quality and bioaccumulation in fish tissue of harmful substances stirred up by dredging	2
Health and safety concerns related to increased traffic and development	3
Danger to recreational users of submerged trees toppled by bank erosion	1
Other Comments with Implications for Health and Safety	
Cumulative effect of discharges on river may offset water quality improvements	4
Instream sedimentation forming bars and causing vessel groundings	1
Need for examination of those licensed to operate recreational craft	1
Concern about ancillary movement of goods and services in emergencies, e.g., bridge destruction	1
Importance of coordination between Corps and Ohio River public water suppliers	1

8.5 INDICATORS OF ENVIRONMENTAL SUSTAINABILITY

Federal, state and local agencies broadly recognize the contribution of effective monitoring and response procedures to the protection of public H&S. As a result, numerous quantitative resources are available that can serve as indicators of the status of particular H&S concerns. Tracking these concerns over time permits an evaluation of H&S sustainability in the context of improving, stable, or declining conditions. Principal H&S concerns and available measures that address these concerns are presented in **Table 8-2.**

8.6 LAWS, REGULATIONS, ORDINANCES AND PROGRAMS

Spill response refers to emergency response activities to barge/tow spills or accidental discharges, or to industrial plant spills or accidental discharges, into the Ohio

River or its tributaries. The Ohio River Valley Sanitation Commission (ORSANCO) has a spill monitoring system in place.

TABLE 8-2
Indicators of Sustainability

Principal Health and Safety Concerns	Available Quantitative Measures to Address the Concerns
Spills of oil, fuel, and other hazardous or toxic materials.	USEPA Emergency Response Notification System (ERNS) spills database.
Potential sources of contamination associated with past or present activities – industrial sites, landfills, underground storage tanks.	USEPA databases for sites on the National Priority List (NPL); Resource Conservation and Recovery Act (RCRA) Corrective Action (CORRACTS) sites; and candidate NPL or CORRACTS sites under USEPA or state review. RCRA permitted treatment, storage and disposal (TSD) facilities; RCRA registered generators of hazardous waste; and state lists of leaking underground storage tanks (LUST), registered aboveground/underground storage tanks (AST, UST), and solid waste landfills, incinerators, or transfer stations (SWLF).
Accidents associated with commercial or recreational boating.	Boating accident records maintained by US Coast Guard (USCG) and states.
Health impacts of water quality – boating, swimming, fish consumption.	ORSANCO water quality data and indices for the Ohio River. State and federal fish consumption advisories.
Noise impacts from construction activity, commercial transportation, other sources.	USDOT/FHA Highway Construction Noise Methodology (DOT 1981).

Various states along the Ohio River and related federal agencies with pertinent responsibilities already have contingency plans in place to respond to spills or accidental discharges. Section 301 of the Clean Water Act (CWA) requires many industrial facilities to develop and maintain plans for preventing and responding to spills of oil and hazardous substances, such plans are called Spill Prevention Control and Countermeasure (SPCC) Plans (http://www.epa.gov/oilspill/respmgnt.htm).

Boating safety regulations refer to legislation and rules related to the operation of recreational watercraft, including personal watercraft, on the Ohio River. Such regulations are issued by the six states bordering the river, and also by the recreational boating safety program of the U.S. Department of Transportation and U.S. Coast Guard. Federal funding authorized by the Transportation Equity Act for the 21st century is used in conjunction with state revenues to support both educational and enforcement efforts. Marine Safety Offices of the U. S. Coast Guard are responsible for: Homeland Defense Activities, Port Safety & Security, Commercial Vessel Inspection, Pollution Response, Waterways Management & Marine Casualty Investigation.

ORSANCO monitors Ohio River water quality and aquatic ecology. River water quality monitoring for selected parameters is conducted at identified monitoring stations and fish monitoring is conducted via several research programs. ORSANCO also serves as

a repository for information on the quality of river water used for public water supplies. Monitoring data supports health advisories addressing water contact recreational activity.

Table 8-3 presents information on important federal, state, and local regulations and established programs, which directly or indirectly influence H&S (including noise) in the Ohio River study area.

In addition to noise related regulations described in **Table 8-3**, Federal legislation related to noise impacts include the Federal Aid Highway Act of 1970 and the Aviation Safety and Noise Abatement Act of 1979 (HUD, 1985). The Federal Aid Highway Act of 1970 and subsequent amendments established the requirement that noise control be a part of the planning and design of all federally aided highways. The Aviation Safety and Noise Abatement Act of 1979 focuses primarily on noise measurement, mapping, and reduction at airports (Canter, 1996).

TABLE 8-3
Laws, Regulations, Ordinance and Programs Relevant to Health, Safety and/or Noise

Law/Program	Key Components	Relevance to Health, Safety &/or Noise
Occupational Safety and Health Act (National Institute for Occupational Safety and Health)	• Requires employers to provide workers a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress and unsanitary conditions • Created NIOSH to establish standards for workplace health and safety	Provides a comprehensive framework for worker and workplace safety
Emergency Planning and Community Right-to Know Act (a.k.a. SARA Title III) (USEPA and state and local emergency response agencies)	• Requires emergency planning and preparedness at state and local level • Section 304 establishes spill reporting requirements for facilities that release extremely hazardous substances • Section 312 requires certain facilities to file annual toxic chemical release forms.	Provides emergency planning and provides citizens, local governments and local response authorities with information on potential hazards in their community.
Pollution Prevention Act (US Environmental Protection Agency)	• Establishes the policy of pollution prevention, reduction and recycling in an environmental safe manner whenever feasible • Requires facilities filing annual toxic chemical release forms to also file a toxic source reduction and recycling report	Protects public safety by requiring pollution reduction or recycling of hazardous substances, toxic chemicals and toxic and radiological wastes at their sources
National Environmental Policy Act (NEPA) (Council on Environ-mental Quality and other federal agencies)	• Requires preparation of environmental impact assessments for new construction projects by private and governmental agencies • Includes federal government's responsibility to prevent environmental	Provides basic national charter for environmental protection , including efforts that promote human health and

Law/Program	Key Components	Relevance to Health, Safety &/or Noise
	degradation that could become a threat to public health or safety	welfare
Safe Drinking Water Act (SDWA) (U.S. Environmental Protection Agency)	• Provides for establishment of primary regulations for the protection of public health and secondary regulations related to taste, odor and appearance of drinking water	Helps protect public water supplies for approximately three million people who use the Ohio River as their source of drinking water
Oil Pollution Act (U.S. Environmental Protection Agency and U.S. Coast Guard)	• Strengthens governmental ability to prevent & respond to catastrophic oil spills • Requires oil storage facilities and vessels to submit plans detailing how they will respond to large discharges	Protects drinking water supplies and natural resources from pollution & damage from oil spills
Site Remediation Statutes (U.S. Environmental Protection Agency and state regulatory agencies)	• Includes the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA), Resource Conservation and Recovery Act (RCRA) and related state programs that focus on cleanup and restoration of contaminated sites.	Protects human health and the environment and eliminates or reduces the generation of hazardous wastes
Toxic Substances Control Act (U.S. Environmental Protection Agency and state regulatory agencies)	• Designed to establish a system by which all chemicals are evaluated before use to ensure they pose no unnecessary risk to human health, other living organisms, or the environment • Intended to mitigate the hazards of other chemicals already in use	Tries to balance benefits and risks of chemicals in use to ensure human and environmental safety
Corps Permitting Statutes (U.S. Army Corps of Engineers)	• Section 10 of Rivers and Harbors Act (1899) relates to permits for physical obstructions to navigable U.S. waters. • Section 404 of CWA authorizes the Corps to issue permits for the discharge of dredged and fill materials into waters of the U.S.	Includes safeguards for public health and safety.
State Water Quality Certification (Appropriate state or interstate pollution control agencies)	• Section 401 of Clean Water Act requires applicants proposing activity, which may result in discharge to U.S. waters, to provide certification of compliance with state water quality standards.	Provides opportunity for state or interstate scrutiny of health related implications of such actions
Clean Water Act (CWA) (U.S. Environmental Protection Agency)	• Establishes structure for regulating pollution discharges into U.S. waters (NPDES permits) • Requires establishment of water quality standards • Section 301 requires many industrial facilities to develop and maintain plans	Provides a comprehensive framework for water quality protection that includes protecting public health and safety, as well as natural resources

Law/Program	Key Components	Relevance to Health, Safety &/or Noise
	for preventing and responding to spills of oil and hazardous substances, called Spill Prevention Control and Countermeasure Plans (SPCC).	
TMDL Program (U.S. Environmental Protection Agency)	• Increasingly important section (§303) of the Clean water Act; regulates maximum pollutant load a water body can receive and still attain water quality standards.	Helps protect public water supplies for approximately three million people who use Ohio River as their source of drinking water.
Phase 1 & 2 NPDES Program (U.S. Environmental Protection Agency)	• Also developed within the CWA, requires municipalities and certain industrial and construction sites to develop programs to control nonpoint sources of pollution.	Should reduce pollution characteristics of stormwater discharges from urban and industrial zones along the Ohio River.
National CSO Control Policy (U.S. Environmental Protection Agency)	• Published by USEPA, calls for communities to implement long-term plan for combined sewer overflows (CSOs) to comply with the CWA. • Administered through each state's NPDES permit program.	Should reduce pollution from a major urban source, including pathogens harmful to public health
Spill Response (ORSANCO and U.S. Coast Guard)	• Includes emergency response activities for river-related spills and accidental discharges and is related to the Oil Pollution Act and Section 301 of the Clean Water Act.	Minimizes adverse impacts of spills and discharges on mussels and other aquatic life and on water quality
Noise Control Act (USEPA, USDOT, FAA, GSA & state and local governments)	• Directs USEPA to set noise-level criteria and promote an environment free of noise that jeopardizes human health and welfare.	Protects hearing and fosters more orderly environmental conditions
Quiet Communities Act (State and local agencies)	• Amends the Noise Control Act to encourage noise-control programs at the state and community levels.	Extends noise control to local level to protect hearing and foster more orderly environmental conditions
Recreational boating safety regulations and programs (U.S. Coast Guard, U.S. Dept. of Transportation, and state agencies)	• Provides boater safety education and training • Establishes procedures for accident reporting	Enhances safety and enjoyment of recreational boat users on the Ohio River

8.7 PAST TO CURRENT BASELINE CONDITIONS

Project scoping suggested that the most important factors affecting the recent and current status of public H&S includes:

- Hazardous industrial activities

- Hazardous waste sites
- Spills or related accidental discharges
- Recreational boating accidents
- Water quality
- Commercial transportation

Industrial activities located or conducted in proximity to the river may pose one or more types of public risk. These can include pollution point sources, production and disposal of hazardous wastes, and spills of potentially hazardous or polluting materials associated with transfer, storage, and use of the materials. Past industrial activities have contributed to the creation of contaminated sites and landfills that pose ongoing threats to groundwater, surface water, or public health. Raw materials, products, and wastes associated with river oriented industrial activity are transported locally and regionally by barge, rail, and truck transport. These materials are subject to spillage while in transit and especially at material transfer points.

Recreational boating on the Ohio River may be subject to higher levels of risk than would normally be encountered on inland lakes and streams. Strong currents, water level fluctuations, and the presence of barge traffic may be more prevalent on the Ohio River than in other settings. Recreational boating on the Ohio River results in a number of injuries, fatalities, and associated property damage. Boating and other river oriented recreational activities appear to have grown significantly over the past several decades in conjunction with improving water quality. Continued growth of such activities may contribute to more crowded conditions and increased risk of additional accidents.

While overall water quality has improved to the point where almost all of the Ohio River can support recreational activities and consumptive uses most of the time, temporary impacts can still increase risks. Such impacts may include elevated fecal coliform counts in urban areas following wet weather or major spills that threaten drinking water supplies. Additionally, ongoing effects of past contamination are reflected in fish consumption advisories and remediation costs of contaminated sites.

In the context of H&S risks, commercial transportation on the river is most visibly connected with the potential for spills and for potential conflicts with recreational users of the river and adjoining property owners.

8.7.1 Hazardous Site/Spill Databases

Certain industrial activities, waste sites, and spill locations have been recorded in one or more databases. These include sites such as hazardous waste generators or underground storage tank operators that require a permit to operate contaminated sites such as Resource Conservation and Recovery Act (RCRA) listed sites, and sites where reportable spills of oil or hazardous materials have occurred. To obtain a perspective on the distribution of such sites along the full length of the Ohio River, the Corps collected information from all available databases. All records occurring on or within one mile of either bank of the river were selected and mapped. **Table 8-4** summarizes the federal and state databases that were searched and the number of records found for each database type.

This survey identified 3,579 mappable sites. Most sites are listed by more than one database. For example, site 950 in Pittsburgh includes records for a past leaking underground storage tank, current registration of underground tanks, and a reported spill. As would be expected, sites are concentrated in urban and major port areas, but numbers of sites are present along the length of the river. **Supplement 8-A** to this chapter includes an overview of mapped areas, Area Map 1, Detail Map 1 (Pittsburgh), and records for an example site (#950).

TABLE 8-4
Databases Searched to 1 mile of the Ohio River Mainstem

AGENCY	DATABASE	Type of Records	# cited
US EPA	NPL	National Priority List	13
US EPA	CORRACTS	RCRA Corrective Actions	104
STATE	SPL	State equivalent priority list	1
US EPA	RCRA-TSD	RCRA permitted treatment, storage, disposal facilities	27
STATE	SCL	State equivalent CERCLIS list	144
US EPA	CERCLIS/ NFRAP	Sites under review by US EPA	363
STATE/REG/CO	LUST	Leaking Underground Storage Tanks	1081
STATE/REG/CO	SWLF	Solid waste landfills, incinerators, or transfer stations	117
STATE/CO	UST	Registered underground storage tanks	2783
STATE	AST	Registered aboveground storage tanks	180
US EPA	GNRTR	RCRA registered small or large generators of hazardous waste	1526
US EPA/ STATE	SPILLS	ERNS and state spills lists	3069
Source: VISTA 10/25/01 (see Chapter References for complete list of databases).			

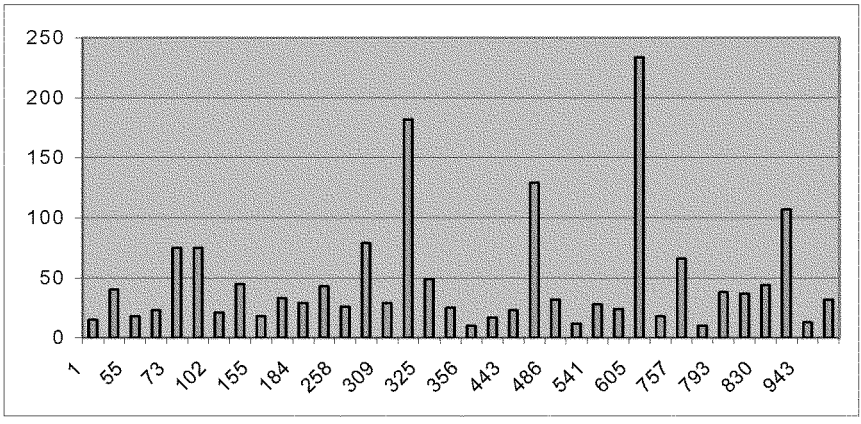
8.7.2 Spill Records

Spill records were difficult to interpret because of the extreme rates of record duplication. Records were collected for the period 1990 – 2000. Of the 3,069 records cited in Table 4, it appears that virtually all state records were duplicates of the national Emergency Response Notification System (ERNS). There were also numerous record duplications within ERNS; the initial total of 2,455 records was reduced to 2,123 after elimination of duplicates. Of this group, 1,700 records located the spill event by river mile.

ERNS is a national computer database system that is used to store information on the sudden and/or accidental release of hazardous substances, including petroleum, into the environment. The ERNS reporting system contains preliminary information on specific releases, including the spill location, the substance released, and the responsible party.

Spill events were not randomly distributed along the 981 miles of river. As might be expected, they are concentrated in the major port and industrial areas. The 1,700 spill records correspond to just 56 discrete River Mile (RM) point locations, ranging from a low of 4 records at Clarksville, IN (RM 605) to a high of 190 at Louisville, KY (also at RM 605). By clustering points that were close together (e.g., RM 602 – 608 for Louisville), spill locations could be summarized as just 36 points along the river. These points are summarized in **Figure 8-1**.

FIGURE 8-1
Distribution of Spill Events along the Ohio River Mainstem



From the above figure, the most frequent spills correspond to the following areas:

- Follansbee, WV area (75 spills, RM 71-75),
- Yorkville, OH to Wheeling, WV (75 spills, RM 85-90),
- Point Pleasant, WV area (79 spills, RM 265-270),
- Kenova, WV/South Point, OH/Catlettsburg, KY area (182 spills, RM 316-318),
- Cincinnati, OH area (129 spills, RM 468-473),
- Louisville, KY area (234 spills, RM 602-608),
- Owensboro, KY (66 spills, RM 757)
- Paducah, KY (107 spills, RM 935)

8.7.3 Recreational Boating and Accidents

Recreational boating accident statistics are compiled and published annually by the US Coast Guard. Data for the accident statistics come from two sources: (1) Boating Accident Report data forwarded to the Coast Guard by jurisdictions with an approved numbering and casualty reporting system and (2) reports of Coast Guard investigations of fatal boating accidents that occurred on waters under Federal jurisdiction. Recreational Boating Accident Investigation data are used if submitted to the Coast Guard and are relied

on as much as possible to provide accurate accident statistics. In the absence of investigations, information is collected from the accident reports filed by boat operators. Information is compiled in the Coast Guard's Recreational Boating Accident Report Database (BARD – see **Supplement 8-B**). Current regulations (33 CFR 173.55) require the operator of any vessel, numbered or used for recreational purposes to file a Boating Accident Report (BAR) when; as a result of an occurrence that involves the vessel or its equipment:

1. A person dies;
2. A person is injured or requires medical treatment beyond first aid, i.e., treatment at a medical facility or by a medical professional other than at the accident scene;
3. Damage to vessels totals $2,000 or more or there is a complete loss of any vessel (prior to July 2, 2001, the property damage threshold was $500);
4. A person disappears from the vessel under circumstances that indicate death or injury.

Users of these boating statistics need to be aware of the following facts that may affect results of analyses of accident report data:

1. The Recreational Vessel Casualty Reporting System does not include every accident involving a recreational vessel. Some accidents are not in the system because they are not required to be reported. Many more accidents are not reported because boaters may be unaware of the law and inherent difficulty in enforcing the law. It is believed that only a small fraction of all non-fatal boating accidents occurring in the United States are reported to the Coast Guard, state, or local law enforcement agencies.
2. Fluctuations from year to year in non-fatal accident statistics may be caused by factors other than the change in the total number of recreational boating accidents. A seemingly small change in the low reporting rate may cause a relatively large change in the statistics. Overall, the more serious the accident, the more frequent the reporting. Therefore, it is believed that nearly all fatal recreational boating accidents are reported (USCG, 2001).

8.7.4 Boating Accident Statistics

Boating accident totals for each state on the Ohio River are in **Table 8-5**. For the period 1997-2001, the six states accounted for 8.8% of all boating accidents nationwide. For the period 1995-2001, accidents on the Ohio River accounted for 4.7% of all boating accidents in the six states. Each state's share of Ohio River accidents varies from a low of 0.7% for Illinois to a high of 34.3% for West Virginia. These shares appear to be approximately consistent with each state's probable relative share of boating activity on the Ohio River. Illinois and Pennsylvania have significant boating opportunities available on other waterways and larger shares of population located away from the Ohio River, thus they would be expected to have the lowest proportions of boating activity on the Ohio River. By contrast, Kentucky and West Virginia, with the highest proportions of boating activity on the Ohio River, have large populations adjacent to the river and relatively fewer boating alternatives elsewhere.

For the Ohio River total of 235 accidents, collision with another vessel was the most common event, accounting for 80 accidents or 34% of the total. Other collisions (floating/sunken objects, docks, etc.) or groundings accounted for 47 events (20%), flooding/swamping, or capsizing the vessel accounted for 25 events (11%), and falling overboard or within the vessel accounted for 21 events (9%). Other types of accidents included fire/explosion (8%), sinking (7%), victims in water struck by boat or prop (4%), skier mishaps (3%), and miscellaneous other (4%).

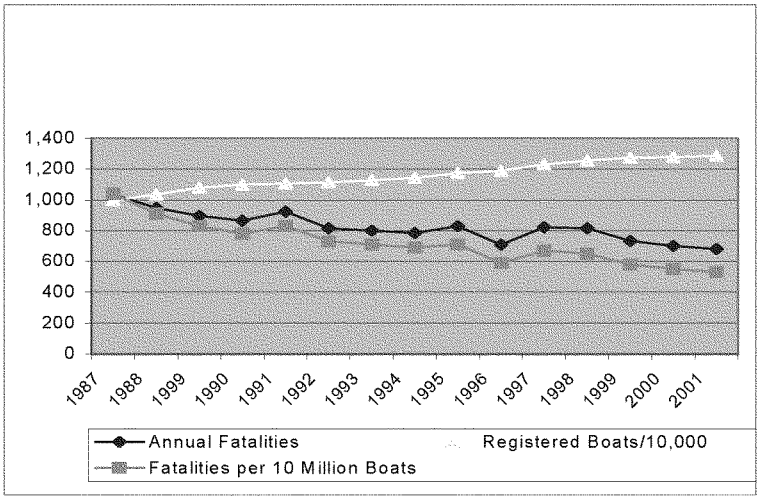
TABLE 8-5
Boating Accidents: State and Ohio River Totals

	1995	1996	1997	1998	1999	2000	2001	Totals (7 yrs)	State Share
Nat'l			8047	8061	7931	7740	6419		
IL-state	164	156	145	159	159	155	108	1046	
IL-OH R.	1	0	1	1	0	3	1	7	0.7%
IN-State	155	143	115	132	150	115	120	930	
IN-OH R.	6	6	10	4	10	6	10	52	5.6%
KY-State	83	95	79	63	75	98	71	564	
KY-OH r.	5	7	7	4	7	11	5	46	8.2%
OH-state	291	242	197	228	232	198	139	1527	
OH-OH R.	14	7	6	5	16	7	7	62	4.1%
PA-state	95	117	119	122	125	88	80	746	
PA-OH R.	4	2	2	2	5	4	0	19	2.5%
WV-state	27	18	20	18	25	20	15	143	
WV-OH R.	9	6	8	5	12	4	5	49	34.3%
Total-6 states	814	771	675	722	766	674	533	4955	
Total-OH R.	39	29	33	21	50	35	28	235	4.7%
Source: USCG, National Boating Statistics									

For the limited years of available data, there is no apparent trend in the annual average number of accidents on the Ohio River. Annual numbers vary widely, from a low of 21 in 1998 to a high of 50 in 1999. Anecdotal comments suggest that high water conditions during peak weeks of the boating season (mid-May through mid-September) significantly reduce the total amount of boating activity in those years and may likely contribute to similar declines in number of accidents in such years. This high annual variability, combined with the relatively small number of annual accidents on the Ohio River, makes it difficult to determine any trends over a limited period of time.

On a national scale, statistics for boating fatalities suggest that a trend towards improved boating safety is occurring. From 1987 through 2001, annual boating fatalities have declined by an average of 1.88% per year or a total of 28.2% over the 15 years of record. During this time, the number of registered boats has grown by a little under 30%. When fatality rates are adjusted for growth in the number of registered boats, fatalities decline by about 2.8% per year or 42.5% over the period of record. These trends are illustrated in **Figure 8-2**.

FIGURE 8-2
National Average Boating Fatalities and Adjusted for Number of Boats



Recreational boating activity and reported boating accidents on the Ohio River are highly concentrated on warm season weekends. The months of June through August account for 71.1% of all accidents, while May through September account for 89.7%. Saturday or Sunday accounts for 62% of all accidents. These figures can be compared to recreational boat lockage data recorded at Emsworth locks in 1999. June through August account for 71.9% of all recreational lockages, May through September account for 96.6% of lockages, and 73.3% of all activity occurs on Saturday or Sunday.

The boating accident reports include the primary cause of each accident and may also list other causes. The list of causal factors can be grouped under three primary categories: human behavior, boat equipment failure, and hazards in the boating environment. **Table 8-6** summarizes the primary causes of boating accidents on the Ohio River.

Human behavior is identified as the principle cause of over 60% of reported boating accidents on the Ohio River. These accidents often occur in good weather on boats in good operating condition. Equipment problems and environmental hazards each account for just fewer than 20% of all accidents. Note that overcrowded conditions (congested waters) is cited on only two occasions. The category for 'secondary causes' refers to additional contributing factors that are recorded on some accident records. These are also predominately related to human behavior and may typically refer to accidents where human mistakes compounded the initial problem of equipment failure or environmental hazards. Finally, the category for 'ambient conditions' records weather and water conditions at the time of the accident. For the Ohio River, 'rough water' often implies high water conditions. Note that accidents occurring during nighttime account for 74 of

223 reports (33%). Lockage data suggest that only about 21% of recreational boating traffic is on the river at night.

TABLE 8-6
Causes of Ohio River Boating Accidents

Principal Causes	1995	1996	1997	1998	1999	2000	2001	totals
Human Behavior								
Alcohol Consumption	4	3	6	1	8	4	2	28
Excessive Speed	3	5	7	4	5	4	0	28
Operator Inexperience	5	1	3	1	0	4	0	14
Operator Inattention	3	3	2	5	7	0	7	27
Careless/reckless operation	1	2	4	1	4	2	0	14
Rules of Road Infraction	1	0	0	0	1	0	0	2
No Proper Lookout	4	3	0	0	3	0	2	12
Over/improper Loading	2	0	0	0	0	1	0	3
Wake	0	0	0	0	2	0	2	4
Passenger/Skier Behavior	1	0	1	1	1	0	0	4
Improper Anchoring	0	0	0	0	0	1	0	1
Total Human Behavior	**24**	**17**	**23**	**13**	**31**	**16**	**13**	**137**
Total Human/223 reports								**61.4%**
Equipment								
Equipment/Mech. Failure	6	5	1	2	4	3	5	26
Ignition Fuel/vapor	0	0	1	0	2	0	0	3
Hull Failure	0	3	0	1	0	4	1	9
Total Equipment	**6**	**8**	**2**	**3**	**6**	**7**	**6**	**38**
Total Equip./223 reports								**17.0%**
Environment								
Hazardous Waters	2	3	4	2	6	4	2	23
Object in Water/submerged	1	0	0	0	1	0	2	4
Restricted Visibility	1	1	0	0	1	1	2	6
Weather	1	0	0	1	3	2	0	7
Congested Waters	0	0	0	0	1	1	0	2
Total Environment	**5**	**4**	**4**	**3**	**12**	**8**	**6**	**42**
Total Environ./223 reports								**18.8%**
Unknown Causes	0	0	1	0	2	1	2	6
Secondary Causes								
Excessive Speed	3	2	3	0	0	0	1	9
Operator Inexperience	2	3	3	4	4	2	1	19
Operator Inattention	3	8	5	2	7	4	2	31
Operator Other	4	2	1	1	6	5	6	25
Equipment Failure	2	1	1	2	0	2	2	10
Hazardous Waters	0	1	2	0	3	3	2	11
Environment Other	1	2	1	1	6	3	8	22
Ambient Conditions[1]								
Rough/Very Rough Water	2	3	5	4	10	8	5	37
Night-time	6	8	17	11	18	8	6	74
Poor Visibility	2	0	1	2	1	4	2	12

[1]Conditions at time of accident, not necessarily causal to accident.

Source: USCG, National Boating Statistics

8.7.5 Boating Accidents and Barge Traffic

Reported recreational boating accidents for the Ohio River from 1995 through 2001 included nine events out of 235 that involved a commercial vessel. Since the Coast Guard records only report accidents involving recreational vehicles, other types of accidents involving commercial vessels (running aground, striking a pier, etc.) would not be included. The nine accidents all involved recreational boats and barge/tow combinations that were underway at the time of the accident.

Three of the accidents resulted in a total of eight fatalities, including one accident that produced six deaths. The principal cause of this most spectacular disaster was listed as restricted vision due to fog and darkness. Improper loading was listed as a secondary factor; the six victims were sharing a 16 to 18 foot open motorboat. The barge/tow was not cited for contributory factors in this case.

For the total of nine accidents, alcohol use was cited as the primary cause of three events and a secondary factor in two additional events. Careless/reckless operation and operator inexperience were each cited as the primary cause of two accidents, while machinery failure and restricted vision were each identified for one accident. Operator inattention was recorded as a secondary factor in three cases and no proper lookout (attributable to the barge operator) was recorded for two cases. Six of the nine cases occurred at night. None of the cases indicated that a crowded condition on the waterway was a contributory factor.

8.7.6 Bacteria Contamination and Monitoring

To protect human health associated with contact recreation, ORSANCO monitors six urban areas (Pittsburgh, Wheeling, Huntington, Cincinnati, Louisville, and Evansville) five times per month from May – October for both fecal coliform and *E. coli.* In May 2001, ORSANCO added monitoring stations at both upstream and downstream locations at the six urban areas, increasing the total number of monitoring stations from six to nineteen. Data generated from the additional sites provide a valuable comparison between bacteria levels upstream and downstream of urban areas on the Ohio River.

From May – October, fecal coliform are not to exceed 400 Colony Forming Units (CFU) per 100 mL in more than ten percent of the samples at a given site, nor should they have a monthly geometric mean greater than 200 CFU per 100 mL. *E. coli* are not to exceed 240 CFU per 100 mL in any single sample, nor to exceed 130 CFU per 100 mL as a monthly geometric mean.

Nine water supply utilities perform analysis for fecal coliform bacteria on their raw intake water and provide these results to ORSANCO on a monthly basis. ORSANCO has adopted a criterion that specifies a maximum monthly geometric mean for fecal coliform of 2000 CFU per 100 mL to protect public drinking water supplies. These sites, added to the 19 urban sites, result in 28 monitoring points for fecal coliform.

There were no violations of the stream criterion to protect public drinking water supplies during calendar year 2001 (the latest year available). During May and June of 2001, five of the six cities recorded at least one violation of the contact recreation standards. From July – October 2001, all cities recorded at least one violation of the contact recreation standards. Additionally, stream criteria to protect human health associated with contact recreation were exceeded at 22 of the 28 sampling sites.

Records for 2001 reflect the general pattern in recent years for bacteriological exceedances in Ohio River urban areas. Exceedances occur annually in most urban areas and are generally associated with high flow conditions. Combined sewer overflows, leakage and overflow from sanitary sewer collection systems, and urban stormwater runoff are suspected as the primary sources of these biological contaminants.

8.7.7 Fish Consumption Advisories

Both federal and state agencies currently publish fish consumption advisories applicable to the Ohio River. The USEPA in 2001 issued a national mercury-based advisory that states: "If you are pregnant or could become pregnant, are nursing a baby, or if you are feeding a young child, limit consumption of freshwater fish caught by family and friends to one meal a week. For adults, one meal is six ounces of cooked fish or eight ounces of uncooked fish; for a young child, one meal is two ounces of cooked fish or three ounces of uncooked fish."

The USEPA advisory is similar to Ohio's statewide mercury advisory, issued in 1997, which advised women of child-bearing age and young children (age 6 and under) to eat no more than one meal per week of fish (any species) from any Ohio body of water or no more than the number of meals specified for the more restrictive advisories listed in the annual advisories. Although the one meal per week advice applies mainly to these sensitive populations, the current general advisory for Ohio, issued in 2003, recommends that everyone follow that advice.

All six of the states bordering the Ohio River have consumption advisories in place for certain species of fish from the river. These advisories primarily focus on the potential presence of certain contaminants and are derived from fish tissue sampling conducted by ORSANCO. This sampling program, initiated in 1976 and modified in 1987, allows appropriate state agencies to use data from the program as the basis for issuing fish consumption advisories. An advisory committee comprised of state health and environmental quality personnel is convened to discuss the data and the need for and basis of fish advisories. Fish advisories are issued, removed or modified by state agency personnel. ORSANCO also facilitates communication among the states to minimize differences in advisories issued for Ohio River fish. Current consumption advisories from USEPA and the six Ohio River states are presented in **Table 8-7**.

TABLE 8-7
Fish Consumption Advisories for the Ohio River

Authority	Fish Species	Applicable Population	Advisory	Contaminant
US EPA	All species	Women, pregnant or nursing	No more than one meal per week	Mercury
Ohio	All species	General population	No more than one meal per week	Mercury
	Freshwater drum, white bass, striped bass hybrid; walleye 17" & over.	General population	No more than one meal per month	PCBs
	Channel catfish under 17," flathead catfish	General population	No more than one meal per 2 months	PCBs, Mercury
	Channel catfish 17" and over, common carp	General population	Do not eat	PCBs
Pennsylvania	All species	General population	No more than one meal per week	Mercury
Pennsylvania , RM 0.0-31.7	Walleye, sauger, white bass, freshwater drum	General population	No more than one meal per month	PCBs
	Carp, channel catfish	General population	Do not eat	PCBs
Pennsylvania , RM 31.7-40.0 (Based on OH & WV advisories).	White bass, hybrid striped bass, freshwater drum, walleye 17" and over	General population	No more than one meal per month	PCBs
	Channel catfish under 17," flathead catfish	General population	6 meals/year	PCBs
	Channel catfish 17" and over, common carp	General population	Do not eat	PCBs
West Virginia	Smallmouth bass, largemouth bass, sauger	General population	No more than one meal per week	PCBs, Mercury, Dioxin*
	White bass, hybrid striped bass, freshwater drum	General population	No more than one meal per month	
	Channel catfish under 17," flathead catfish	General population	6 meals/year	
	Channel catfish 17" and over, common carp	General population	Do not eat	
Kentucky	All species	Special population[1]	No more than one meal per week	Mercury
	Paddlefish (and eggs)	Special population	No consumption	PCBs
		General population	6 meals/year	
	Sauger, black	Special population	One meal/month	PCBs

Authority	Fish Species	Applicable Population	Advisory	Contaminant
	basses, flathead catfish	General population	One meal/week	
	Carp, white bass, drum, hybrid striped bass	Special population	6 meals/year	PCBs
		General population	One meal/month	
	Channel catfish >21" (above Cannelton L&D)	Special population	No consumption	PCBs
		General population	6 meals/year	
	Channel catfish <21" (above Cannelton L&D)	Special population	6 meals/year	PCBs
		General population	One meal/month	
	Channel catfish, blue catfish > 14" (below Cannelton L&D)	Special population	6 meals/year	PCBs
		General population	One meal/month	
	Smallmouth buffalo (above Markland L&D)	Special population	6 meals/year	PCBs
		General population	One meal/month	
	Blue catfish <14," bigmouth buffalo (below Cannelton)	Special population	One meal/month	PCBs
		General population	One meal/week	
Indiana	Carp to 16"; channel catfish, freshwater drum, largemouth bass, Sauger/walleye/ saugeye, & spotted bass to 13," flathead catfish to 17," white/striped/hybrid bass to 9"	General population	One meal/week	PCBs
	Carp > 16," channel catfish 13"-21," flathead catfish 17"-20," drum, largemouth bass, spotted bass >13," sauger/walleye/sauge ye 13"-23," smallmouth buffalo 15"-17," white/striped/hybrid bass 9"-20," paddlefish any size	General population	One meal/month	PCBs
	Channel catfish 21'-26," flathead catfish 20"-24," sauger/walleye/sauge ye >23," smallmouth bass 13"-15," smallmouth buffalo >17," white/striped/hybrid bass >20"	General population	One meal/2 months	PCBs

Authority	Fish Species	Applicable Population	Advisory	Contaminant
	Channel catfish >26," flathead catfish >24," smallmouth bass >15,"	General population	Do not eat	PCBs
Illinois	Predator fish (fish eaters)	Special population[2]	One meal/week	Mercury
	Channel catfish >15," blue catfish any size, drum <14,"	General population	One meal/week	PCBs
	Drum >14," carp any size	General population	One meal/month	PCBs
	Sauger any size	General population	One meal/month	PCBs & mercury
	Largemouth bass	Special population[2]	One meal/month	PCBs
		General population	One meal/week	

[1]KY special population: women of childbearing age and children 6 years and younger.
[2]IL special population: pregnant or nursing women, women of childbearing age and children younger than 15 years of age
PCBs = Polychlorinated Biphenyls
Source: Ohio http://www.epa.state.oh.us/dsw/fishadvisory/overview.html
p://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/FishAdvis/fishadvisory.htm
WV http://www.wvdhhr.org/fish/
KY http://water.nr.state.ky.us/dow/dwfish.htm
IN http://www.in.gov/isdh/dataandstats/fish/fish_adv_index.htm
IL http://www.idph.state.il.us/public/press03/fish.htm
US EPA http://www.epa.gov/waterscience/fish/

8.8 INTERACTIONS WITH OTHER VALUED ENVIRONMENTAL COMPONENTS (VECs)

Impacts of river-related health and safety on other resources, ecosystems, and human communities are most obviously related to the Transportation, Recreation, and Socioeconomic VECs. H&S issues are also related to Air and Water Quality and to biological resources (aquatic or riparian organisms, including Threatened and Endangered (T&E) Species). Current health and safety risk factors result from the scale of activities such as navigation or recreation and the level of success achieved by present efforts to reduce those risks. As river related activities continue to grow, additional measures will be needed to prevent any resurgence of risk factors. VEC interactions are illustrated in **Table 8-8**.

TABLE 8-8
Interactions of Health & Safety with Other VECs

VEC	Risk Factors & Impacts	Past/Present Trends	Future Trends	Comments
Transport-ation & Traffic	Source of fuel/oil spills, hazardous cargo spills, other cargo spills, boating accidents.	Reduced spills (all types due to regulatory standards and improved handling procedures. Boating accidents minimized through training & equipment upgrades.	Increases in commercial traffic contribute to additional risk factors.	Role of lock & dam projects and O&M activity to promote safe commercial use of the river.
Recreation	Boating accidents, fuel/oil spills.	Accidents/spills minimized through boater education, boat safety equipment standards, regulatory presence.	Increases in recreational traffic contribute to additional risk factors.	Role of Coast Guard, state & municipal authorities to establish & enforce safe boating standards, especially in congested use areas
Socio-Economic	Spills/discharge s from river oriented industry Also, from CSOs, urban stormwater, nonpoint sources.	Frequent exceedances of contact recreation standards (fecal coliform &/or E. coli) from CSO & urban stormwater sources. Reduced industrial spills/discharges per historic levels.	CSO, urban stormwater, nonpoint sources need further improvement to reduce discharge impacts.	Role of state EPAs to monitor & maintain stability/containment of former waste disposal sites, contaminated industrial sites, and contaminated fills in Ohio River.
Water Quality	Primary impacts are as described for Transportation and SocioEconomics .	Significant past improvements contribute to increased recreational uses & sustainability of drinking water sources and industrial and transportation uses.	Population growth & increased recreational use may offset some water quality improvements.	Role of ORSANCO to monitor water quality parameters on Ohio River mainstem and major tributaries.
Air Quality	Acid rain and ground-level ozone continue to pose health risks to local and down-wind populations.	Significant past improvements contribute to improved health, sustainability of coal utilities & other industrial activity.	Ongoing implementation of long term source reduction programs will contribute to reduced emissions and improve air quality.	More stringent ozone standards will require expanded local programs plus new programs in new areas.

VEC	Risk Factors & Impacts	Past/Present Trends	Future Trends	Comments
Biological Resources (aquatic, riparian, T&E).	Aquatic & riparian organisms are susceptible to same spectrum of impacts as described previously for people.	Significant past improvements contribute to recovering populations and sustainability of many Ohio River organisms.	Nutrients from non-point sources may be important risk factor for local and downstream impacts to biological resources.	Expansion & recovery of aquatic & riparian habitats may be more important than further pollution reductions to expanded populations, species diversity & sustainability.
Cultural Resources	Acid rain impacts affect historic structures, grave markers, etc.	Significant past improvements contribute to reduced impacts.	Continued air quality improvements should contribute to further reduction of impacts.	Less direct interaction than previous VECs.
Land Use	Health impacts of urban stormwater.	Risks from urban stormwater will increase with continued urban expansion.	Long term risks of increased travel associated with continued urban expansion.	Less direct interaction than previous VECs.

8.9 RELEVANT ACTIONS AFFECTING HEALTH, SAFETY, AND NOISE

RFFAs were evaluated utilizing the Matrix (see Exhibit A, Procedure and Methods, for discussion of the RFFA analysis methodology). The matrix evaluation process resulted in identification of 23 RFFAs with potentially high importance to future health and safety issues and 46 RFFAs with medium importance. Completion of a separate RFFA matrix for noise related issues identified 8 RFFAs with potentially high importance and 19 with medium importance. These RFFAs are presented in **Table 8-9**, which combines the results of the health and safety and noise matrices.

Following the summation of RFFA findings, H&S issues are discussed in the context of the continued operation of the Ohio River navigation system. Further discussion addresses activities that are dependent upon continued operation of the new system and other actions that are less directly related to continued operation of the system.

8.9.1 Health and Safety RFFAs

RFFAs that are likely to be of high importance to future H&S issues include: new locks or extensions, levees and floodwalls, and several key regulatory activities. RFFAs that constitute important risks to health and safety include: port development and dredging, pool maintenance, commercial navigation in general, marina development, on-water recreation, hazardous waste sites, floods, and severe storms.

TABLE 8-9
RFFA Cumulative Effects Matrix for Human Health, Safety & Noise VECs

RFFA[1]	Time Period[2]	Occurrence	Location on River[4]	Impact-H & S	Importance- H&S	Impact-Noise	Importance- Noise
Navigation Investment Actions							
Lock Extensions/New Locks/Replacement or Rehabilitation	A	H	SL	+	H	-	M
L&D operation and maintenance	A	H	SL	+	M	-	L
Non-structural navigation improvements	A	H	E	+	H	+	M
Dam replacement and rehabilitation	A	H	SL	+	M	-	M
Other Corps Actions							
Channel dredging/dredged material disposal	A	H	E	0	M	-	L
Navigation aids - Construction and O&M	A	H	E	+	M	-	L
Flood damage reduction projects							
levees/floodwalls	A	L	SL	+	H	-	L
dry dams, other projects off mainstem	A	L	SL	+	M	-	L
channel modifications	A	H	SL	+	M	-	L
nonstructural measures (e.g., relocation)	A	H	SL	+	L	+	M
Emergency streambank stabilization (Sec. 14)	A	H	SL	+	M	-	L
Modification of Corps structures for environmental improvements (Sec. 1135)	A	M	SL		L	-	L
Environmental restoration of aquatic ecosystems (Sec. 206)	A	M	SL	+	L	-	M
Recreation facilities - Construction and O&M	A	H	SL	+	M	-	M
ERP Projects - 5 categories	A	M?	SL	+	L	-	M
Port development (Sec. 107) and maintenance dredging	A	H	SL	-	H	-	M
Pool maintenance	A	H	E	-	H	-	L
"But for" Actions							
Commercial Navigation							
barge queuing	A	H	SL	-	H	-	L
fleeting areas/barge storage	A	H	SL	-	H	-	M
terminals	A	H	SL	-	H	-	M
multi-modal sites	A	H	SL	-	H	-	H
increased traffic	A	H	E	-	H	-	M
dispersed barge traffic	A	H	E	-	H	-	L
barge/tow tech/"green" design	A	H	E	+	M	?	
accidents/spills	A	H	E	-	H	-	L
Coast Guard Nav. Aids - Construction, O&M	A	H	E	+	M	-	L
Instream sand and gravel mining	A	H	SL	-	M	-	H
Floodplain sand and gravel mining	A	H	SL		L	-	H
Limestone aggregates mining	A	H	SL		L	-	H
Coal utilities	A	H	SL	-	M	-	H

RFFA[1]	Time Period[2]	Occurrence	Location on River[4]	Impact-H & S	Importance- H&S	Impact-Noise	Importance- Noise
Other coal industries	A	M/L?	SL	-	M	-	H
Hydropower on dams	A	M	SL	-	M	?	
Water intakes	A	M?	SL	0	M	-	L
Industrial users, excluding coal-related	A	H	SL	-	M	-	H
Recreation facilities - Construction and O&M	A	H	SL	+	M	-	M
Actions by Others							
Park development and operations	A	H	SL	+	L	+	L
Public forest development and operations	A	H	SL	+	L		
Floodplain development							
residential	A	H	SL	-	M	-	L
commercial	A	H	SL	-	M	-	M
industrial	A	H	SL	-	M	-	H
Crossings							
bridges	A	H	SL	-	H	-	M
utility	A	H	SL	-	M	-	L
industrial	A	H	SL	-	M	-	L
Riverbed crossings	A	H	SL	-	M	-	L
Marina development & operation	A	H	SL	-	H	-	M
Water -based recreation							
boating	A	H	E	-	H	-	L
fishing	A	H	E	-	H	?	
PWCs	A	H	E	-	H	-	L
hunting	A	H	SL	0	M	?	
wildlife watching	A	H	E		L	?	
sight-seeing	A	H	E	-	L	?	
Silviculture	A	H	R	-	L	-	L
Agriculture	A	H	R	-	M	?	
WWTP discharges							
municipal	A	H	U	-	M	?	
industrial	A	H	U	-	M	?	
onsite systems	A	H	E	-	M	?	
Stormwater discharges	A	H	U	-	M	?	
Brownfields redevelopment	A	H	U	+	M	-	L
Trail/bikeway development	A	H	E	+	L	-	L
Casinos	A	H	SL	-	L	-	M
Hazardous waste sites	A	H	SL,U	-	H	-	L
Natural Climatic Events							
floods	A	H	E	-	H		
droughts	A	H	E	-	M		
severe storms	A	H	E	-	H		
earthquakes	A	L	E	-	M	-	L
ice	A	H	E	-	M		
Regulatory Environment							
Phase I & 2 NPDES program	A	H	SL,	+	M	?	

RFFA[1]	Time Period[2]	Occurrence	Location on River[4]	Impact-H & S	Importance- H&S	Impact-Noise	Importance- Noise
			U				
TMDLs	A	H	E	+	M	?	
Site remediation	A	H	SL	+	M	-	L
More stringent quality standards for environmental media	A	H	E	+	M	+	M
Pollutant source control	A	H	E	+	M	?	
Wetland Mitigation Banking	A	H	SL	+	L	-	L
Carbon sequestration	2,3	M	E	+	M	+	L
Farmland preservation	A	H	SL, R	+	M	?	
Effluent trading	A	H	SL	+	M	?	
Agricultural discharges	A	H	SL, R	-	M	?	
Pollution Prevention	A	H	SL, U	+	L	+	M
Emissions trading	A	H	SL	+	M	?	
COE permitting programs	A	H	E	+	L	+	M
Small navigation projects	A	H	SL, U	-	M	-	L
Boating safety regulations	A	H	E	+	H	?	
ORSANCO monitoring program	A	H	E	+	H	?	
Spill response	A	H	E	+	H	?	
Information and FOIA	A	H	E	+	L	+	L
Environmental Awareness Education	A	H	E	+	M	+	L
ESA (Endangered Species Act)	A	H	SL	+	L	+	L
Environmental sustainability practices	2,3	M	E	+	M	+	L

[1] Reasonably Foreseeable Future Actions
[2] Time period in which the RFFA may occur
1 = within 10 years, 2 = in 10 - 25 years, 3 = in 25 - 60 years, A = all time periods
[3] Occurrence probability or likelihood RFFA will happen
H = high M = medium L= low
[4] Location or setting on river where RFFA is expected to occur
U = upper (Pittsburgh - Huntington), M = middle (below Huntington - Louisville)
L = lower ((below Louisville - mouth), E = along entire length of river
SL = specific location, e.g., locks and dams, U = urban setting, R = rural setting

New locks or extensions would provide increased capacity for commercial and recreational lockages and would relieve congestion associated with queuing, particularly when the main lock chambers are closed for maintenance. This would facilitate safer, more efficient movement of river traffic (see Chapter 10 - Transportation and Traffic, for a more complete discussion of congestion-related impacts). Potential accidents, injuries, and environmental impacts are important H&S risks associated with all major construction

projects. Strict enforcement of onsite safety regulations (OSHA, plus state standards) for workers and the public and proper disposal of all construction materials, effluents, and other wastes would minimize risks. River congestion/conflicts during construction could be alleviated through effective notification of navigation industry and other river users and also alleviated with helper boats near L/Ds.

Levees and floodwalls provide flood protection for adjacent communities. However, depending on levee design, they may limit emergency access to the river.

Key regulatory activities include boating safety regulations, ORSANCO monitoring, and spill response. More stringent boating regulations, better educational programs, and consistent enforcement should result in safer boating on the Ohio River. Efforts to standardize regulations and programs along the entire river (through a consortium of states or through federal leadership) would be more effective than state-by-state efforts. ORSANCO's various ongoing monitoring programs provide environmental and human health information and are now widely accessible on the ORSANCO website. Awareness of ORSANCO and its programs seems to have increased in recent years. Measures currently in place by ORSANCO, Coast Guard, USACE, USEPA, and various state agencies should continue to reduce accidental spills and their adverse effects on water quality, particularly on drinking water and edible fish. Spill detection and notification systems along the river have become increasingly sophisticated in the last 20 years.

Various activities related to commercial navigation have the potential to negatively affect recreational use, safety, and water quality. These include queuing, fleeting operations, and activities at terminals or multi-modal sites. Ongoing negative safety concerns include traffic congestion and spills during transfer of materials at these facilities. Continued growth of commercial traffic, activities such as operations outside the navigation channel, and periods of extreme high or low flows can increase these associated risks.

Spills of hazardous or toxic materials are an ongoing problem associated with commercial navigation and river-oriented industry. Areas of particular concern include vessel fueling operations (including midstream), barge loading/off-loading operations, queuing areas and river reaches with heavy debris. Short to long-term impacts are associated with exposure of spills and public drinking water intakes. Spills also may damage or contaminate shoreline areas.

Pool maintenance is also closely related to maintenance and growth of the commercial navigation system. Significant H&S issues are related to the maintenance of existing pool elevations. These include maintenance of the nine-foot minimum depth for navigation, safety of operations and prevention of spills at barge loading/off-loading operations, and maintenance of minimum depths at water intakes and discharge outfalls. Potential raising/lowering of pool levels would have health and safety impacts of very high importance to affected populations.

Port development and dredging involves potentially significant safety concerns and user conflicts, depending on levels of activity and management. These issues also would

increase with future growth of commercial traffic. Development of recreational marinas also suggests potential conflicts with commercial vessels and related safety concerns depending on carrying capacity of particular river reaches.

On-water recreation includes fishing from boats, other recreational boating, and operation of personal watercraft (PWC). Conflicts between these activities and other non-recreational river users cause safety concerns that become more critical as localized crowding increases. Season, time of day, and popularity of individual river reaches add to these risk factors. Continued growth of recreational activities will broaden applicability of these issues.

Hazardous waste sites, if not properly managed and regulated, pose continuing threats to public health and safety related to water pollution, air pollution, and quality of life.

Floods and/or severe storms can be extremely dangerous to river users because of heavy precipitation, high winds, rising water, swift currents, heavy debris, and lightning. These can increase the potential for river-related accidents, including vessel casualties, barge breakaways, and pollution incidents. Although these occurrences cannot be prevented, better forecasting, improved communications, and enhanced boater education can help prevent injuries and deaths as well as minimize environmental impacts.

RFFAs judged likely to be of medium importance to future health and safety issues include: various activities associated with maintenance of the commercial navigation system, numerous regulatory activities, development of recreational facilities, and redevelopment of brownfields. RFFAs that constitute potentially moderate importance risks to H&S include: various river-oriented industrial activities, instream sand/gravel mining, floodplain development, crossings, agriculture, waste water treatment plant discharges, stormwater discharges, and other severe climatic events.

Maintenance of the commercial navigation system includes L&D operation and maintenance (O&M), non-structural navigation improvements, lock and dam replacement/rehabilitation, channel dredging, navigation aids, flood damage reduction projects, and emergency streambank stabilization. O&M activities ease congestion, maintain a safe operating environment for commercial traffic and other river users, warn of hazards, and facilitate efficient movement of traffic. This group of activities was assigned medium importance since most effort focuses on maintenance of existing conditions.

Important or potentially important regulatory activities include NPDES programs, TMDLs, site remediation, more stringent future quality standards for environmental media, pollutant source control, carbon sequestration, farmland preservation, effluent trading, agricultural discharges, emissions trading, small navigation projects, environmental awareness education, and environmental sustainability practices. These programs may benefit or maintain water, air, or soil quality and thus contribute to a more healthful environment.

Development of recreational facilities includes riverfront parks, trailways, bikeways, playgrounds, picnic areas, etc., in addition to fishing and boating access. Positive long-term health benefits are related to such increased recreational opportunities. Brownfields redevelopment creates general long-term benefits for public health and safety, as well as for land use and socioeconomics.

Various river-oriented industrial/commercial activities include instream sand/gravel mining, coal utilities, other industries, hydropower on dams, water intakes, floodplain commercial/industrial development, agriculture, WWTP discharges, and bridge, utility, and industrial crossings. Issues related to these activities may include ongoing safety concerns related to traffic and spills during transfer of materials at these facilities, potential impacts of point source pollutants on water quality and related health conditions, and increased risk factors during severe weather or periods of extreme high or low flows. Temporary risk factors also occur during construction or major repair activity at these sites.

8.9.2 Noise RFFAs

RFFAs that are likely to be of high importance to future noise issues are associated with general industrial activities that may produce significant, ongoing, or frequent noise impacts. These include mining activities, coal utilities, other river-oriented industries, and future industrial developments. Noise impacts of potentially medium importance include construction activity at large project sites such as lock extensions, dam rehabilitation, various other Corps activities, and major construction activity conducted by others. In all cases, the potential importance of noise impacts is a function of the population, including sensitive groups, living in close proximity to the source of the noise. With respect to Corps activities, initiatives such as nonstructural navigation improvements or nonstructural flood damage reduction programs can have a moderate positive impact by reducing or eliminating some construction activity and its noise related impacts.

8.9.3 Continued Operation of the Ohio River Navigation System

This section addresses H&S impacts that may result from continued operation of L&D projects on the Ohio River. These direct actions include lock construction and maintenance, navigation system operation and maintenance, commercial navigation, recreation, and other activities. Such actions meet the "but for" criteria to the extent they are dependent on continued operation and maintenance of the navigation system. Potential impacts from each class of activities are summarized.

8.9.3.1 Construction of Auxiliary Lock Chamber Extensions

Temporary H&S impacts would occur at the lock site as a result of auxiliary lock chamber expansion projects. Temporary impacts would also occur on the Ohio River above and below the site. Following completion of auxiliary lock chamber expansions, increased capacity for commercial and recreational lockages would relieve congestion when the main chamber is closed for maintenance and would facilitate safer, more efficient movement of river traffic.

Potential impacts from construction of the lock chamber extensions include:

- Impacts to human H&S of the public from construction activities
- Noise impacts from construction activities
- The risk of spills during construction activities and increased queuing.
- Impacts to human H&S of recreational boaters and commercial navigation from increased towboat congestion.

Procedures to protect human H&S would be similar at each of the potential lock chamber extension sites. Variations would be required to meet local site conditions, address site-specific construction/demolition requirements, and comply with individual state regulatory standards. The following excerpts from the Environmental Impact Statement (EIS) for J.T.Myers and Greenup Locks Improvement illustrate these H&S procedures ($USACE_a$):

> During lock construction, several safety procedures would be in place. All existing recreation areas would be restricted from public access during the construction period. A notice of construction activity would be given to the navigation industry. Helper boats would be used to assist navigation traffic. Dive plans and blasting plans would be developed and coordinated with the lockmaster. On-site safety personnel would oversee safety procedures and enforce provisions of Environmental Manual (EM) 385-1-1 *Safety and Health Requirements Manual,* US Army Corps of Engineers. Any blasting would require approval of a blasting plan by the appropriate state agency.
>
> To help prevent harm to workers or the public from accidental spills during construction, a control and disposal plan would be in effect. The plan would include procedures for addressing the filling and disposal of hydraulic oil, manner of draining pipe, disposition of valves, pipe and related construction debris, manner of collection and storage of used or spilt oil, and the manner of collection, storage and disposal of used absorbent or absorbent pads. Records would be provided to confirm that work was performed in the approved manner.
>
> All transportation operations associated with the project would take place in accordance with the EM 385-1-1 *Safety and Health Requirements Manual.* A plan for transporting materials and equipment to the site would indicate haul routes, method of transportation, safety precautions, and method of handling and storage. Materials kept on the construction site would be stored in accordance with manufacturer instructions as well as with EM 385-1-1 *Safety and Health Requirements Manual.*
>
> The approved drilling and blasting plan would show the location and depth of holes, inclination of wedge-cut holes, amount and strength of explosives per round and per hole, sequence of firing and time delays, and estimated length of pull per blast. All work would be done in accordance with EM 385-1-1 *Safety and Health Requirements Manual* and applicable state and federal regulations. This plan would also address the required communication, coordination and monitoring efforts with

the lockmaster regarding the impacts of the blasting on navigation and day-to-day operation of the existing locks and dam.

Operations during the construction process would require periodic closures of the main and/or auxiliary chambers. Associated towboat traffic safety issues would be the same as during any emergencies or planned closures without construction. Closures would cause area towboat densities to increase, posing additional risks to tow crews and pleasure craft operators. Timing of main chamber closures and minimizing individual closure duration would minimize increased towboat densities and associated risks.

Fencing and warning signs would be used to minimize the risk of public exposure to or interference with construction activities. Signs would be provided where needed to regulate traffic, warn of hazardous conditions, establish restrictions and restricted areas, and to direct and inform the public. Disposal of all construction materials, effluents, and other wastes would be handled in accordance with EM 385-1-1 *Safety and Health Requirements Manual*. Any materials that might be burned throughout the construction process (i.e., cleared trees and shrubs) would follow applicable state procedures or permit requirements for open burning.

All diving performed under the proposed action would be in accordance with the rules and regulations prescribed by the Department of Labor's Occupational, Safety and Health Administration (OSHA), as per commercial diving operations: Part 1910 of Title 29 of the code of Federal Regulations, Subpart T; the Corps *Safety and Health Requirements Manual,* EM 385-1-1; Corps of Engineers Diving Regulations and ER 385-1-86. All diving activities would be conducted with full knowledge and close coordination with an authorized Corps representative. Divers would not enter the water or move from the prescribed location without the approval of the lockmaster and an authorized Corps representative.

A distance of approximately one mile from the site to the nearest sensitive receptors would primarily mitigate noise levels from construction activities. Maximum noise levels were calculated not to exceed 101.85 dBA at the site, according to the FHA's Highway Construction Noise Methodology (USDOT 1981). At one mile from the site, noise levels would not exceed 62 dBA, a "normally acceptable" level for sensitive receptors such as nursing homes or schools.

If sensitive receptors are significantly closer to the construction site at other locks, additional measures such as sound barriers may be required to reduce noise impacts.

8.9.3.2 Lock Maintenance, Repair, and Rehabilitation.

Ongoing commercial use of the L&D facilities will require periodic upkeep and maintenance. This will include major and minor repairs of both primary and auxiliary locks. As existing locks age, the need for such repairs will become more frequent. The frequency of repairs increases in proportion to ongoing increases in the amount of commercial traffic (and resultant use of the lock chambers) on the Ohio River. For the 60-

year study period, these repair events are expected to occur on an average of once every five years for each L&D project ($USACE_a$). Effects from major lock rehabilitation would be similar to those of repairs, but would likely occur less frequently and would be of longer duration.

Each lock repair event will produce similar but smaller scale temporary health and safety risks in the vicinity of the construction activities. Repair events would include temporary lock closures and the H&S risks associated with barge queuing. Measures to protect H&S would closely resemble those described above for lock extension activity.

Completion of auxiliary lock chamber extensions will reduce the need for some major and minor repair events and would contribute to reduced repair activities and associated H&S risks in three ways:

- It may be feasible to schedule each lock extension so as to eliminate one complete auxiliary chamber repair event.
- Each extension creates a lock in new condition, allowing for a longer time interval between auxiliary chamber repair events.
- Finally, the original full-sized lock will be used less, since total lockages can be shared equally between the two full sized locks allowing for a longer time between the main chamber repair events ($USACE_a$-1, Sept. 2000).

8.9.3.3 Nonstructural Navigation Improvements

Nonstructural navigation improvements refer to project alternatives that do not involve L&D infrastructure. These include efficiency measures such as vessel scheduling and prioritization, self-help coordination among towboat coordinators, and expanded mooring facilities near locks and dams. Some measures, such as expanded mooring facilities, may require modest, temporary health and safety risks during construction and installation. Other measures such as vessel scheduling may require improved communication and position tracking systems, but would involve no installation risks. It is expected that nonstructural navigation improvements will be implemented wherever they prove to be feasible.

Nonstructural navigation improvements offer a great opportunity to reduce risks associated with commercial traffic in the vicinity of the locks. Reduced congestion, queuing, toe-ins, and groundings would facilitate safer, more efficient movement of river traffic.

8.9.3.4 Other Direct Actions by U.S. Army Corps of Engineers

The Corps conducts a wide variety of other activities within the Ohio River study area. Activities with potentially significant H&S impacts include: major rehabilitation of the dams, channel maintenance dredging, construction of levees or floodwalls, channel modifications for flood control, nonstructural flood reduction programs such as relocation of threatened housing, emergency streambank stabilization (Sec. 14), modification of Corps projects for environmental improvement (Sec. 1135), environmental restoration of

aquatic ecosystems (Sec. 206), construction and operation of recreation facilities, ecosystem restoration projects, and port development and maintenance dredging.

The largest of these activities involves major rehabilitation of the dams (as opposed to rehabilitation of lock chambers). While the timing of rehabilitation projects is subject to numerous variables, this activity primarily corresponds to the useful life cycle of the dam. Of the 20 dams currently on the river, six have been rehabilitated in the past two decades, at an average age of 60 years following their initial construction. Assuming a life cycle of 60 years, all of the dams currently on the Ohio River may require major rehabilitation during the 60-year cycle of the study period.

H&S impacts from dam rehabilitation projects will be similar to construction site impacts described previously for lock extension projects. The activities will require similar measures to reduce risks to public health and safety.

Channel maintenance dredging involves removal and disposal of sand and gravel deposits from the navigation channel of the Ohio River to maintain a nine-foot depth. Notices to navigation, warning signs in the vicinity of active dredges, and operational plans in conformity with EM 385-1-1 *Safety and Health Requirements Manual* are routinely employed to protect public health and safety in the vicinity of dredging operations ($USACE_d$). Effective maintenance of the nine-foot navigation channel is a critical part of assuring safe operating conditions for commercial traffic on the Ohio River. Maintenance of navigation aids that are the responsibility of the Corps is also important to the provision of safe operating conditions.

8.9.3.5 Commercial Navigation

The full spectrum of commercial navigation activities constitutes a significant source of H&S impacts within the Ohio River floodplain. Barge traffic is potentially subject to accidents in the form of collisions with other watercraft, collisions with fixed objects such as bridge abutments, and spills of fuel, oil, or cargo. The scope of such risks was illustrated during January, 2005 when two accidents occurred within days of each other during high water conditions on the upper Ohio River. At Montgomery Lock and Dam, four crew members' lives were lost when strong currents pushed their tugboat and six barges of coal through the dam following an attempt to lock through upbound. At Belleville Lock and Dam, nine coal barges broke away from their tug and were swept into the dam. Four of the barges became trapped against the dam abutments, preventing closure of the dam gates and contributing to a partial dewatering of the pool until salvage workers were able to remove the barges following nearly 3 weeks of effort. Additional risks of accidental spills are associated with fleeting areas, terminals, other port related facilities, and industrial activities that utilize commercial navigation services. These facilities store, transfer, or process petroleum products, chemical stocks, and other toxic or hazardous materials.

Congestion adds to these transportation-related risks. Congestion occurs in the form of urban or commercial concentrations of port activity, barge queuing, seasonal and daily peaks of recreational boating, and the ongoing growth of barge traffic. The quantity of

materials shipped on the Ohio River grew steadily from the 1920's through the early 1990's, leveled off during the past decade, and is expected to continue to grow at a slower pace for the foreseeable future. This continued growth will require new terminals, expanded capacity at existing terminals, and expanded land based storage and transfer facilities, all of which will contribute to increased H&S risks along the Ohio River.

Continued expansion of existing facilities and establishment of new facilities can be expected to occur in response to general economic/population expansion and subsequent growth in loads carried by barge transport. Traffic projections prepared by the Corps indicate that barge traffic growth will occur independently of navigation improvements addressed by this study. The second generation of high-lift L&D projects, which was largely completed in 1980, provides sufficient capacity to meet most of the projected barge traffic growth ($USACE_a$-3). However, completion of lock extensions, nonstructural improvements and other upgrades to the navigation system can improve safety conditions by reducing congestion impacts associated with lock maintenance activities.

Barge queuing is an aspect of commercial navigation that is an important factor to several VECs (including Air, Fish, Mussels, and Water Quality)) because of the environmental impacts of such activity. Queuing occurs as a result of both lock extension and lock repair activities, which are referred to as construction delay queuing. Queuing also occurs during heavy traffic when locks are in normal operation (operational delays).

8.9.3.6 Mining Activities

Mining activities along the Ohio River contribute to general H&S risks; including navigation hazards and potential spills of equipment, fuel, or other pollutants. Instream sand and gravel mining poses the greater risk, with lesser risks from floodplain sand and gravel mining and floodplain limestone aggregates mining. Continued growth of such activities is expected to occur in proportion to ongoing population and urbanization/development growth along the Ohio River. These mining activities tend to congregate along the river in areas proximate to growing metropolitan areas or in support of major construction projects such as Olmsted dam or major highway or bridge projects.

Mining activity along the Ohio River benefits directly from the availability of barge transport. If such transport were not available, some mining activity would be replaced by mine sites in other locations. Thus, mining activity at least partially meets the 'but for' criteria. However, capacity within the existing navigation system is adequate to accommodate any anticipated growth of mining activity and no additional growth would be expected as a result of the navigation improvements addressed by this study.

8.9.3.7 Industrial Activities

A number of industrial activities congregate along the Ohio River or its major tributaries and benefit directly from the availability of barge transport and/or availability of water supplies associated with maintenance of the navigation pools. While some of these activities are conducted within major urban centers, much is dispersed through less populated areas along the length of the floodplain. These include coal-fired electric

utilities, other industries utilizing coal as a fuel and/or process material, and other industries with bulk transport needs. Continued growth of these industries is expected to occur in proportion to ongoing population and urbanization/development growth within the broader economy of the Ohio Valley region or the nation at large.

Ongoing safety concerns related to these facilities include the risk of spills during transfer of materials and traffic congestion in the vicinity of barge terminals. Some activities, such as refineries or oil storage/transfer, pose important point source spill risks.

These industrial activities account for the majority of projected growth in barge transport on the Ohio River system. In fact, coal transport alone currently accounts for more than 55% of all barge traffic on the Ohio River and is projected to account for a large percentage of traffic for the foreseeable future.

8.9.3.8 Recreational Activities

Recreational boating and related activities and the infrastructure of marinas, parks, and other support facilities compete with commercial navigation for use of the Ohio River. Other facilities supporting boating and non-boating activities include urban or rural riverfront parks, riverfront hotel/restaurant complexes, and casino boat/resort complexes.

Although boating and related recreational activity occurs throughout the river, the greatest concentrations can be found in urban riverfront settings. These areas frequently coincide with concentrations of commercial navigation in the vicinity of urban port facilities and industrial activities. The recent rate of growth of recreational activity appears to outpace population and development growth rates and is expected to continue to do so for the foreseeable future. See Chapter 9, Recreation, for additional discussion and study findings related to these issues.

While potential conflicts between recreational and commercial navigation are an important H&S concern, it is also important to recognize that recreational use of the river imposes H&S impacts independently of commercial navigation activities. Indeed, the vast majority of boating accidents involve only recreational vessels. Dockside or shoreline fueling of recreational boats also poses a significant risk of fuel and oil spills.

8.9.4 Indirect Action Sources of Impacts on River-Related Health and Safety

Indirect actions include activities which may derive some benefit from existence of the improved navigation system, but would likely have developed regardless of navigation system improvements and would be expected to persist with or without maintenance or additional improvements to navigation. These include:

1) Bridges and other crossings - New bridges across the Ohio River may occur at the rate of one or two per decade during the next 60 years. Two bridges are currently proposed for the Louisville area that may be constructed within the next twenty years (KYINbridges). Associated H&S risks include potential accidental spills or release of contaminants in sediments during construction, potential collisions between

vessels and construction structures, noise impacts, and general public safety risks in the vicinity of construction sites. Public communications, fencing, warning signs, construction plans, and accident or spill contingency plans similar to those discussed previously for lock extension construction would be required for this type of project.

2) Brownfields redevelopment - The availability of funding support for redevelopment of brownfields and other former contaminated sites is contributing to reutilization of some of these formerly abandoned sites. Limited availability of undeveloped land within some areas of the floodplain further reinforces reuse of formerly developed sites. These abandoned or underutilized sites represent an important portion of historic urban/commercial development patterns and are an important component of many redevelopment programs. Successful redevelopment of such sites should include removal or stabilization of buried contaminants and thus contribute to reduced public health risks.

3) Transportation - Highways and railroads constitute a significant land use pattern throughout the Ohio River floodplain. In some portions of the upper river, roads and track are in place along both banks. Just as industrial growth is expected to occur in proportion to ongoing population and urbanization/development, expansion of transportation capacity can be expected to grow proportionally.

4) Natural climatic events - Original settlement patterns along the Ohio River were directly influenced by flood patterns and indirectly influenced by periodic events such as severe storms or drought. Completion of the L&D navigation system, in conjunction with levees and floodwalls on the main stem and flood control reservoirs throughout the watershed, has significantly reduced the impact of flooding events. Additionally, the 100 and 500-year floodplains are fairly well defined along the main stem. Current and potential future improvements in environmental monitoring and communications technologies should continue to contribute to reduced H&S risks associated with flood events, and

5) The regulatory environment - Several regulatory programs are critically important to H&S issues on the Ohio River. These include the spill prevention and response requirements of Section 301 of CWA, boating safety regulations administered by states and the Coast Guard, and system-wide monitoring activities of ORSANCO. Regulatory programs of secondary importance include CWA amendments addressing storm water, non-point sources, and TMDL standards; site remediation standards under RCRA, CERCLA, and SARA; and future emission standards under CAA, CWA, and other regulations.

8.10 CUMULATIVE EFFECTS AND ENVIRONMENTAL SUSTAINABILITY

One of the seven environmental operating principles of the Corps is to strive to achieve environmental sustainability (ES). ES is defined as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation, and maintenance to improve the

quality of life for present and future generations. Accordingly, ES represents an "ultimate test" whereby the significance of CE can be evaluated. This test is applicable for programmatic impact studies wherein a broad, "high altitude" perspective is utilized. An Analysis of Environmental Sustainability (AES) has been and is being used in several other programmatic studies by the Corps. In fact, AES is perceived as an emerging integrator for impact studies in the United States and internationally, particularly in Europe.

The AES approach used herein consisted of three steps: (1) identification of "common effects" on health and safety parameters from the High and Medium importance RFFAs as delineated in the pertinent RFFA matrix; (2) selection of indicators for ES for health and safety, and their grouping, as appropriate; and (3) consideration of the "connections" between the common effects and the indicator groups. The output of the AES consists of a qualitative (descriptive) discussion of the "connections," with the discussion derived from some quantitative data and scientific information, along with professional judgment. The final output addresses the following questions – what is the current ES for health and safety, and is it expected to improve or decline in the future? Three categories of ES are used to answer these questions. The following specific definitions were used:

- Not sustainable – the composite conditions for the selected indicators of ES for H&S do not reflect conditions that would facilitate attainment of acceptable standards or would not maintain existing standards in concert with rising risk factors associated with increasing activity.

- Marginally sustainable – the composite conditions for the selected indicators of ES for H&S are such that the attainment of acceptable standards is accomplished for the majority, but not all, of the river miles in the Ohio River: however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES of H&S for the Ohio River).

- Sustainable – the composite conditions for the selected indicators of ES for H&S are such that the attainment of acceptable standards is accomplished for essentially all of the river miles in the Ohio River, and such standards are maintained in concert with rising risk factors associated with increasing activity. Further, the conditions of the indicators exceed regulatory thresholds and various governmental programs are in place to control point and nonpoint pollution sources, to emphasize pollution reduction in the river, to prevent and/or respond to spill events, and to regulate risk factors associated with boating activity on the river.

Common effects of multiple actions have been previously discussed in the sections entitled "Interactions with Other VECs" and "Relevant Actions Affecting Health, Safety and Noise." These common effects result in groups of actions (risk factors) affecting worker health and safety, boating safety, and public health concerns related to water quality (drinking water, contact recreation, and fish consumption).

Indicators or groups of indicators of ES were identified earlier in the section entitled "Indicators of Environmental Sustainability," and relevant information on them have been presented in the section entitled "Past to Current Baseline Conditions." Regarding their relevance for ES, the following rationale is appropriate:

- measures of key water quality parameters

  - fecal coliform – related to fecal matter contamination from humans or other animals, whether from point or nonpoint sources at specific locations along the river; can also be used as a threshold indicator since the standard is 2000 fecal coliforms/100 ml for drinking water and 400/100 ml for contact recreation.
  - *E. coli* – related to fecal matter contamination from humans or other animals, whether from point or nonpoint sources at specific locations along the river; can also be used as a threshold indicator since the standard is 240/100 ml for contact recreation.

- measures of fish tissue contamination and resultant fish consumption advisories – guidelines for fish consumption are based on risk factors applied to the general population and to more sensitive subpopulations such as young children. They reflect relative progress in long-term efforts to remove pollutants or prevent their introduction to aquatic systems.

- level of conformance with state and federal water quality standards, including attainment of permissible use designations – water quality standards are based on various use designations, with the level of conformance representing a composite indicator of a sustainable aquatic resource for human use including contact recreation

- level of conformance with state and federal air quality standards (Chapter 7 - Air Quality) – these standards include ambient air quality standards, point source controls, industry or group source emission caps, and equipment performance standards

- boating accident statistics can indicate relative risk factors of boating at various locations on the river – trends in accident statistics reflect effectiveness of educational and regulatory efforts to promote and enforce safer boating practices

- effectiveness of spill response, monitoring programs, and related precautionary measures – these represent both direct and indirect programs which are focused on more effective management of health and safety impacts through prevention or minimization

- level of conformance with state and federal worker health and safety standards, including noise management at construction sites, accident prevention, use of protective equipment, and monitoring and enforcement actions

- effectiveness of oversight of permitted activities such as RCRA hazardous waste generators and monitoring of recovery processes at inventoried sites – these represent ongoing programs to minimize discharges from production of hazardous materials or wastes and efforts to clean up previously contaminated sites contributing to reduced risk factors associated with these sites and activities.

For the purposes of this analysis, the above indicators are grouped into three tiers for the AES. The three tiers are as follows:

- first tier – "scientific measures of quality or risk factors"

  (1) water quality parameters (fecal coliform and *E. coli* bacteria, and fish tissue analysis for specified contaminants)

  (2) conformance with air, water quality, and other regulatory standards

- second tier – "positive actions related to minimization of risk factors"

  (1) point source control and nonpoint source control programs

  (2) boating safety programs, education, and enforcement

  (3) spill response, monitoring programs, and related precautionary measures

- third tier – "composite indicators of health and safety sustainability;" this includes measures developed from multiple indicators

  (1) attainment of permissible use designations

  (2) sustain acceptable standards for public health risks

Finally, the indicators and tiers are displayed into three tables, with each coinciding with the three groups of actions with common effects. **Tables 8-10 through 8-12** are on the following pages.

Table 8-10 relates to RFFAs affecting worker/workplace H&S, plus populations affected by construction or other workplace activities. Measures to protect the safety of workers and others affected by these actions are well documented and are discussed in some detail in the section titled "Relevant Actions Affecting Health, Safety, and Noise." These measures have contributed to significant improvements compared to past levels of risk. Further, spill-related programs and precautionary measures are expected to reduce accidental releases from construction sites and other workplace activities. As a result of these current and anticipated future efforts, it is expected that acceptable standards for public health risks will continue to be consistently attained.

Table 8-11 relates to RFFAs associated with commercial and recreational traffic on the Ohio River. Federal and state efforts have focused on: (1) higher standards for boating

safety equipment, (2) improved education for both commercial and recreational boaters, (3) establishment and enforcement of prohibitions of alcohol consumption by boaters, and (4) improved operational rules such as no wake zones in crowded areas. Further improvements to lock and dam infrastructure, navigation aids, as well as other components of the river navigation system can be expected to contribute to improved safety conditions for all boaters. Additionally, comprehensive efforts to minimize transportation-related spills and respond effectively to spills that do occur have significantly reduced H&S impacts of these sources. Continued improvements through broader education requirements, equipment/technology/communication improvements, and implementation of higher standards should achieve sustainability, even with anticipated future increases in commercial and recreational boating traffic.

Three public health concerns that are affected by water quality issues are illustrated in **Table 8-12**. These include drinking water supplies, contact recreation, and fish consumption. Water quality issues are discussed in detail in Chapter 3, Water Quality and Sediment Quality, and much of that discussion regarding the benefits of improving water quality is applicable to these public health issues. The discussions clearly demonstrate the fundamental improvements in water quality from the unsustainable conditions of the recent past.

With respect to present day conditions, availability of threshold water quality parameters for drinking water and contact recreation along with consumption advisories for fish adds further detail specific to human health impact concerns. Water quality monitoring records indicate that coliform levels rarely exceed safety thresholds for drinking water supplies, while these same monitoring efforts further protect drinking water sources by facilitating timely closure of intakes whenever contamination is detected. However, coliform and *E. coli* levels in urban areas frequently exceed threshold levels for contact recreation. Sources associated with these contaminants, such as combined sewer overflows (CSO), sanitary sewer overflows (SSO), and urban stormwater are proving to be difficult and expensive to clean up. While the levels of some fish tissue contaminants such as PCBs and chlordane are continuing to decline in samples from the Ohio River, levels of mercury appear to be more persistent even as risk factors associated with consumption of mercury tainted fish are being elevated. Conflicting fish consumption advisories between some of the states bordering the Ohio River adds an additional layer of doubt to the public consumer. These trends suggest that the safety of drinking water supplies is sustainable, but that contact recreation and fish consumption should be considered only marginally sustainable at the present time.

With respect to future trends for contact recreation and fish consumption, current regulatory programs appear not to be making as much progress as they should. Phase I and II NPDES programs for stormwater runoff have been implemented. Clear demonstrations of runoff water quality improvements are difficult to substantiate. Problems associated with CSOs and SSOs stem from older wastewater collection systems that are often in severely degraded condition. High costs associated with upgrading or modernizing these systems contribute to the lack of progress. Efforts to implement more effective regulatory standards such as TMDLs for aquatic resources or air emission standards for mercury may be years or decades from demonstrated effectiveness. Given the uncertainties of future

TABLE 8-10

AES Tiers for Risk Factors Affecting Workplace Health and Safety

Actions Affecting Workplace Health and Safety	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Lock extensions/new locks/ replacement or rehabilitation (H) • Dam replacement and rehabilitation (H) • Channel dredging (M) • Flood damage reduction projects (all types, M) • Commercial navigation (all categories, M/H) • Mining activities (H) • General industrial activities (M/H) • Other construction/industrial maintenance (M)	• Water Quality Parameters • Conformance with Air and Water Quality Standards	• Point source control and nonpoint source control programs • Boating safety programs, education and enforcement • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain acceptable standards for public health risks

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TABLE 8-11

AES Tiers for Risk Factors Affecting Commercial and Recreational Boating Safety

Actions Affecting Boating Safety	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Navigation investment actions (all types – improved safety, M) • Navigation maintenance: dredging, buoys & markers, M) • Commercial navigation (all categories, M/H) • Instream mining, (M) • Marina development & operations (h) • Water-based recreation (all types, H) • Floods, severe storms (H) • Boating safety regulations (H) • Spill prevention/response (H)	• Water Quality Parameters • Conformance with Air and Water Quality Standards	• Point source control and nonpoint source control programs • Boating safety programs, education and enforcement • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain acceptable standards for public health risks

TABLE 8-12

AES Tiers for Water Quality Factors Affecting Public Health – Drinking Water, Contact Recreation, Fish Consumption

Actions Affecting Public Health	Scientific Measures of Quality	Positive Actions Related to Source Control	Composite Indicators of Aquatic Ecosystem Sustainability
• Urban Stormwater, CSOs, SSOs (H) • Accidents/spills (H). • Hazardous waste sites (H). • Dredging/instream mining (H). • WWTP discharges (M). • Agricultural runoff (M). • Phase I & II NPDES (H). • TMDL standards (H). • Water quality monitoring (H).	• Water Quality Parameters • Conformance with Air and Water Quality Standards	• Point source control and nonpoint source control programs • Boating safety programs, education and enforcement • Spill Response, Monitoring, and Precautionary Measures	• Attainment of Permissible Use Designations • Sustain acceptable standards for public health risks

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progress in these areas, contact recreation and fish consumption should be considered marginally sustainable for the foreseeable future.

8.11 CONCLUSIONS

In the time period prior to 1920 and continuing into the 1960-70s, H&S issues on the Ohio River represented a broad spectrum of risk factors. Construction and workplace conditions were generally more dangerous than at present; spills and discharges from commercial navigation, river oriented industries, and untreated municipal effluents contributed to a variety of public health risks; and little or no information was available to advise the public of ambient risk levels associated with river oriented activity.

While individual risk factors no doubt varied significantly from time to time, most H&S related issues for the period are categorized in **Figure 8-3** as 'marginally sustainable.' However, activities that involved more direct exposure to water quality risk factors are categorized as 'not sustainable' in **Figure 8-4**.

Improvements to water quality, reduced risks of spills and faster response, improved workplace safety standards, and effective safety standards for recreational boating have all combined to make the Ohio River a safer place to work, live, and play. These improved present day conditions result in a 'sustainable' classification in **Figure 8-3**. Improved conditions have also contributed to reduce risk factors associated with contact recreation and fish consumption. However, problems associated with continued exceedances of biological standards, persistence of some contaminants associated with fish consumption, and mixed signals regarding fish consumption standards result in a present time classification of 'marginally sustainable' for these activities.

With respect to the future, most H&S issues are expected to remain in the 'sustainable' rankings. It is important to note, however, that continued growth of commercial navigation, recreational activity, river oriented industries, and other uses of the river will require continued improvements in management and regulation of H&S issues just to maintain the status quo.

While improvement of risk factors associated with contact recreation and fish consumption is expected to continue, these factors are kept in the 'marginally sustainable' category as a conservative estimate of potential trends. Some of the efforts required to achieve continued improvement, such as rehabilitation of sanitary sewer systems to eliminate CSO and SSO, or reduction of mercury emissions from coal combustion will require significant investments and long periods of time to achieve results.

FIGURE 8-3.
Health & Safety for Workplace and Boating Activities

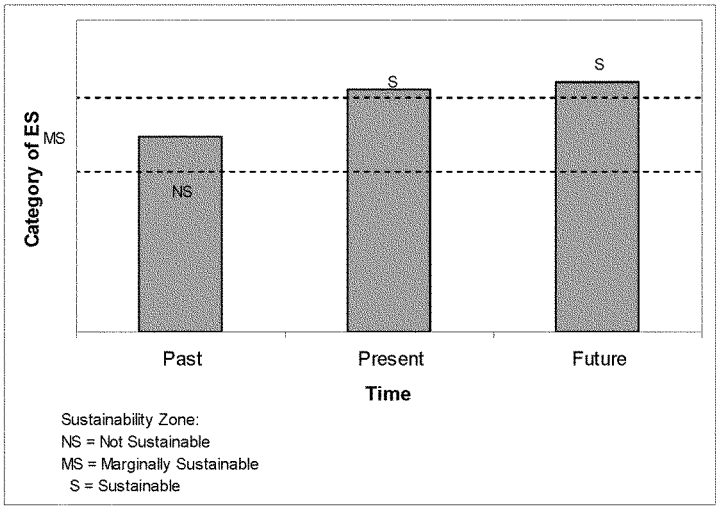
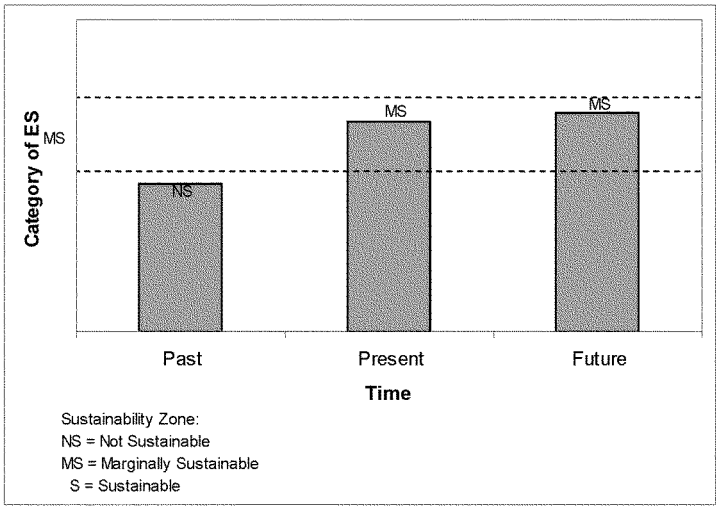


FIGURE 8-4
Health & Safety for Contact Recreation and Fish Consumption



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1) Document MR Main Report & EIS
2) Document EC Economics Appendix
3) Document EC Attachment 3 – ORS Traffic Demand Forecast
4) Document ED-2 Greenup L&D Engineering Site Appendix

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U.S. Department of Housing and Urban Development. 1985. The Noise Guidebook. Washington, D.C.

U. S. Department of Transportation. 1981. Federal Highway Administration's Highway Construction Noise Methodology.

Additional sources of information include databases searched by Fidelity National Information Solutions (formerly VISTAinfo) in Fall 2001:

NPL
The agency release date for National Priorities List was July, 2001.

The NPL Report is the US EPA's registry of the nation's worst uncontrolled or abandoned hazardous waste sites. NPL sites are targeted for possible long-term remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

SPL
The agency release date for Category List was June, 1997.
This database is provided by the Illinois Environmental Protection Agency. The agency may be contacted at: 217-782-6762.

SPL
The agency release date for Hazardous Waste Response Sites was May, 2001.
This database is provided by the Department of Environmental Management, Office of Environmental Response. The agency may be contacted at: 317-308-3052.

SPL
The agency release date for Annual Report of Hazardous Waste Disposal Sites was May,
2001.
This database is provided by the Department of Natural Resources, Superfund Section. The agency may be contacted at: 573-751-3176.

SPL
The agency release date for Hazardous Sites Cleanup Program Site List was July, 2001.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-783-7816.

CERCLIS
The agency release date for Comprehensive Environmental Response, Compensation and Liability Information Sys was July, 2001.
The CERCLIS database is a comprehensive listing of known or suspected uncontrolled or abandoned hazardous waste sites. These sites have either been investigated, or are currently under investigation by the U.S. EPA for the release, or threatened release of hazardous substances. Once a site is placed in CERCLIS, it may be subjected to several levels of review and evaluation, and ultimately placed on the National Priorities List (NPL).

NFRAP
The agency release date for No Further Remedial Action Planned was July, 2001.
The No Further Remedial Action Planned Report (NFRAP), also known as the CERCLIS Archive, contains information pertaining to sites which have been removed from the U.S. EPA's CERCLIS database. NFRAP sites may be sites where, following an initial investigation, either no contamination was found, contamination was removed quickly without need for the site to be placed on the NPL, or the contamination was not serious enough to require federal Superfund action or NPL consideration.

SCL
The agency release date for Site Remediation Program List was August, 2001.
This database is provided by the Illinois Environmental Protection Agency, Remedial Project Management Division. The agency may be contacted at: 217-782-0462.

SCL
The agency release date for Voluntary Cleanup List was June, 2001.
This database is provided by the Department of Environmental Management. The agency may be contacted at: 317-308-3023.

SCL
The agency release date for State Cleanup List was January, 1999.
This database is provided by the Department of Environmental Management. The agency may be contacted at: 317-308-3023.

SCL
The agency release date for State Leads List was October, 2000.
This database is provided by the Department of Environmental Protection. The agency may be contacted at: 502-564-6716. The Kentucky State Leads List is an inventory of potential hazardous substance and waste disposal sites located within the state. In addition, Kentucky uses the U.S. EPA CERCLIS database as an additional source of known or potentially contaminated sites in the State, and for the purpose of tracking sites to be investigated under the Preliminary Assessment/Site Investigation program for potential Superfund listing.

SCL
The agency release date for Master Sites List was March, 1999.
This historical database is provided by the Ohio Environmental Protection Agency. The agency may be contacted at: 614-644-2924.

SCL
The agency release date for Land Recycling Program was July, 2001.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-783-7816.

CORRACTS
The agency release date for RCRIS Corrective Action Sites was June, 2000.
The CORRACTS database contains information concerning RCRA facilities that have conducted, or are currently conducting a corrective action. A Corrective Action Order is issued pursuant to RCRA Section 3008 (h) when there has been a release of hazardous waste or constituents into the environment from a RCRA facility. Corrective actions may also be imposed as a requirement of receiving and maintaining a TSDF permit.

ERNS

The agency release date for Emergency Response Notification System was December, 2000.

ERNS is a national computer database system that is used to store information on the sudden and/or accidental release of hazardous substances, including petroleum, into the environment. The ERNS reporting system contains preliminary information on specific releases, including the spill location, the substance released, and the responsible party.

RCRIS-TSD

The agency release date for RCRIS Treatment, Storage and Disposal Facilities was June,
2000.

The EPA's Resource Conservation and Recovery Act (RCRA) Program identifies and tracks hazardous waste from the point of generation to the point of disposal. The RCRA Facilities database is a compilation by the EPA of facilities which report generation, storage, transportation, treatment or disposal of hazardous waste. RCRA TSDs are facilities which treat, store and/or dispose of hazardous waste.

RCRIS-TSDC

The agency release date for RCRIS TSDs Subject to Corrective Action was June, 2000.

The EPA's Resource Conservation and Recovery Act (RCRA) Program identifies and tracks hazardous waste from the point of generation to the point of disposal. The RCRA Facilities database is a compilation by the EPA of facilities which report generation, storage, transportation, treatment or disposal of hazardous waste. RCRA TSDCs are treatment, storage and/or disposal facilities that are subject to corrective action under RCRA.

RCRA-LQG

The agency release date for RCRIS Large Quantity Generators was June, 2000.

The EPA's Resource Conservation and Recovery Act (RCRA) Program identifies and tracks hazardous waste from the point of generation to the point of disposal. The RCRA Facilities database is a compilation by the EPA of facilities which report generation, storage, transportation, treatment or disposal of hazardous waste. RCRA Large Generators are facilities which generate at least 1000 kg./month of non-acutely hazardous waste (or 1 kg./month of acutely hazardous waste).

RCRIS-SQG

The agency release date for RCRIS Small Quantity Generators was June, 2000.

The EPA's Resource Conservation and Recovery Act (RCRA) Program identifies and tracks hazardous waste from the point of generation to the point of disposal. The RCRA Facilities database is a compilation by the EPA of facilities which report generation, storage, transportation, treatment or disposal of hazardous waste. RCRA Small Quantity Generators are facilities which generate less than 1000 kg./month of non-acutely hazardous waste.

SWLF
The agency release date for USGS Solid Waste Landfills was December, 1991.
This database is provided by the United States Geological Survey. The agency may be contacted at: 703-648-5613.

SWLF
The agency release date for Special Waste Site List was January, 1990.
This database is provided by the Illinois Environmental Protection Agency. The agency may be contacted at: 217-524-3306.

SWLF
The agency release date for Active Permitted Municipal Waste Transfer Stations was September, 1996.
This database is provided by the Illinois Environmental Protection Agency. The agency may be contacted at: 217-524-3865.

SWLF
The agency release date for Land-Based Disposal Sites was July, 1998.
The Landfill Sites of Illinois (Land Based Disposal Sites) database was assembled from several sources including the U.S. EPA, the Illinois Environmental Protection Agency and studies sponsored by WMRC. The GIS coverage includes data for over 3000 waste sites of various types.

SWLF
The agency release date for Storage, Treatment, Recyclers, Incinerators Processors was
October, 1998.
This database is provided by the Illinois Environmental Protection Agency. The agency may be contacted at: 217-524-3306.

SWLF
The agency release date for Solid Waste Landfill Subject to State Surcharge was January,
2000.
This database is provided by the Illinois Environmental Protection Agency. The agency may be contacted at: 217-782-6761.

SWLF
The agency release date for Special Waste Disposal Sites was September, 2000.
This database is provided by the Department of Environmental Management, Office of Solid and Hazardous Waste Mgmt. The agency may be contacted at: 317-232-0066.

SWLF
The agency release date for Permitted Solid Waste Facilities was March, 2001.
This database is provided by the Department of Environmental Management. The

agency may be contacted at: 317-232-0066.

SWLF

The agency release date for Inactive Solid Waste Landfills was January, 1999.

This database is provided by the Department of Environmental Management. The agency may be contacted at: 317-232-0066.

SWLF

The agency release date for Active Solid Waste Disposal Facilities was September, 1999.

This database is provided by the Natural Resources Environmental Protection Division of Waste Management. The agency may be contacted at: 502-564-6716.

SWLF

The agency release date for All Sites List was October, 2000.

This database is provided by the Natural Resources Environmental Protection Division of Waste Management. The agency may be contacted at: 502-564-6716.

SWLF

The agency release date for Inactive Solid Waste Facilities List was July, 1995.

This database is provided by the Department of Natural Resources, Waste Management Program.

SWLF

The agency release date for Certified Hazardous Waste Resource Recovery Facilities was

June, 2001.

This database is provided by the Department of Natural Resources. The agency may be contacted at: 573-751-5401.

SWLF

The agency release date for Permitted Solid Waste Facilities was May, 2001.

This database is provided by the Department of Natural Resources, Waste Management Program. The agency may be contacted at: 573-751-5401.

SWLF

The agency release date for Closed Solid Waste Landfills was March, 1995.

This database is provided by the Ohio Environmental Protection Agency (One time only list).

SWLF

The agency release date for Licensed Solid Waste Facilities was May, 2001.

This database is provided by the Ohio Environmental Protection Agency, Division of Solid Infectious Waste. The agency may be contacted at: 614-728-5326.

SWLF
The agency release date for Delisted and Closed Landfills was May, 2001.
This database is provided by the Ohio Environmental Protection Agency, Division of Solid Infectious Waste.

SWLF
The agency release date for Solid Waste Transfer Stations was August, 1991.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-783-7816.

SWLF
The agency release date for Inactive Solid Waste Facilities was July, 1994.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-787-7381.

SWLF
The agency release date for Solid Waste Inventory was August, 1998.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-787-7381.

SWLF
The agency release date for Priority Waste Tire Piles List was July, 2001.
This database is provided by the Department of Environmental Protection, Bureau of Waste Management. The agency may be contacted at: 717-787-7381.

SWLF
The agency release date for Certificate of Approval for Disposal was June, 1992.
This database is provided by the Division of Natural Resources, Waste Management Section.

SWLF
The agency release date for Class D1 Processing Facilities was May, 1998.
This database is provided by the Division of Natural Resources, Waste Management Section. The agency may be contacted at: 304-558-6350.

SWLF
The agency release date for Industrial Landfills was September, 1998.
This database is provided by the Division of Natural Resources, Environmental Protection. The agency may be contacted at: 304-759-0515.

SWLF
The agency release date for Municipal Solid Waste Landfills was February, 1999.
This database is provided by the Division of Natural Resources, Solid Waste Management Office. The agency may be contacted at: 304-558-6350.

SWLF
The agency release date for Transfer Stations was June, 2001.
This database is provided by the Division of Natural Resources, Waste Management Section. The agency may be contacted at: 304-558-6350.

SWLF-REG
The agency release date for Solid Waste Landfills was March, 1988.
This database is provided by the Northeastern Illinois Planning Commission. The agency may be contacted at: 312-454-0401.

SPILLS
The agency release date for Spills was May, 2001.
This database is provided by the Department of Environmental Management. The agency may be contacted at: 317-308-3023.

SPILLS
The agency release date for Spills was April, 1999.
This database is provided by the Ohio Environmental Protection Agency. The agency may be contacted at: 614-644-2084.

LUST
The agency release date for Leaking Underground Storage Tanks was August, 2001.
This database is provided by the Illinois Environmental Protection Agency, Division of Land Pollution Control. The agency may be contacted at: 217-782-6762.

LUST
The agency release date for Leaking Underground Storage Tanks was May, 2001.
This database is provided by the Department of Environmental Management. The agency may be contacted at: 317-308-3023.

LUST
The agency release date for Leaking Underground Storage Tanks - Active and Inactive was April, 2001.
This database is provided by the Department of Natural Resources, LUST Program. The agency may be contacted at: 573-751-6822.

LUST
The agency release date for Leaking Underground Storage Tanks was June, 2001.
This database is provided by the Department of Commerce, Division of State Fire Marshall. The agency may be contacted at: 614-752-7926.

LUST
The agency release date for List of Confirmed Releases was May, 2001.
This database is provided by the Department of Environmental Regulation. The agency may be contacted at: 717-772-5599.

LUST
The agency release date for Leaking Underground Storage Tanks - Active and Inactive was May, 2001.
This database is provided by the Division of Natural Resources, Division of Waste Management. The agency may be contacted at: 304-759-0515.

UST
The agency release date for Underground Storage Tanks was February, 2001.
This database is provided by the Office of the Illinois Fire Marshall. The agency may be contacted at: 217-528-8936. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

UST
The agency release date for Underground Storage Tanks was May, 2001.
This database is provided by the Department of Environmental Management, UST Section. The agency may be contacted at: 317-308-3023. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

UST
The agency release date for Underground Storage Tanks was January, 2001.
This database is provided by the Department of Environmental Protection, Division of Waste Management-UST Section. The agency may be contacted at: 502-564-5174. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

UST
The agency release date for Underground Storage Tanks was April, 2001.
This database is provided by the Department of Natural Resources. The agency may be contacted at: 573-751-6822. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

UST
The agency release date for Underground Storage Tanks was June, 2001.
This database is provided by the Department of Commerce, Division of State Fire Marshall. The agency may be contacted at: 614-752-7926. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

UST
The agency release date for Underground and Aboveground Storage Tanks was June, 2001.
This database is provided by the Department of Environmental Protection, Bureau of Water Quality Mgmt. The agency may be contacted at: 717-772-5599. Be advised that some states do not require registration of heating oil tanks, especially those used for

residential purposes.

UST

The agency release date for Underground Storage Tanks - Active and Inactive was June,

2001.

This database is provided by the Division of Natural Resources, Division of Waste Management. The agency may be contacted at: 304-759-0515. Be advised that some states do not require registration of heating oil tanks, especially those used for residential purposes.

AST

The agency release date for Aboveground and Underground Storage Tanks was July, 1999.

This database is provided by the Department of Environmental Protection, Bureau of Water Quality Mgmt. The agency may be contacted at: 717-772-5599.

AST

The agency release date for Aboveground Storage Tanks was June, 2001.

This database is provided by the Department of Environmental Protection, Bureau of Water Quality Mgmt. The agency may be contacted at: 717-772-5599.

AST

The agency release date for Aboveground Storage Tanks was April, 2001.

This database is provided by the Department of Natural Resources. The agency may be contacted at: 573-751-6822.

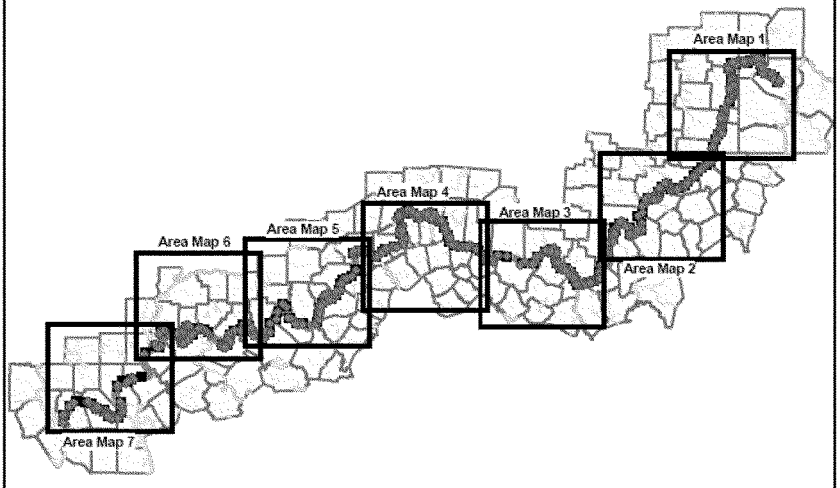
SUPPLEMENT 8-A

EXAMPLE MAPS AND RECORDS FROM

SITE DATABASE SEARCH

SITE ASSESSMENT - SPECIAL PROJECT (ALL DATABASES SEARCHED TO 1 MILE)

Overview Map



Subject Centerline

Search Area

Risk Sites

Risk Sites Plotted as Polygons

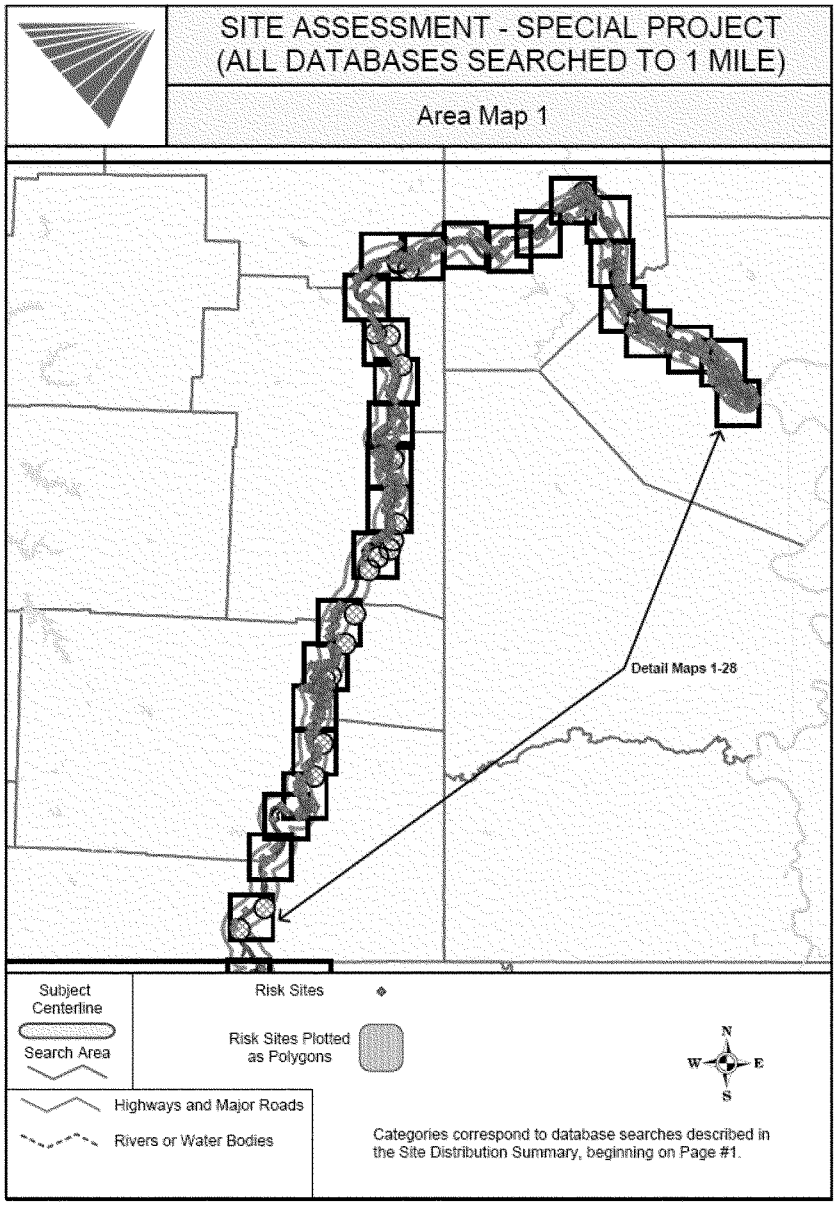
Highways and Major Roads

Rivers or Water Bodies

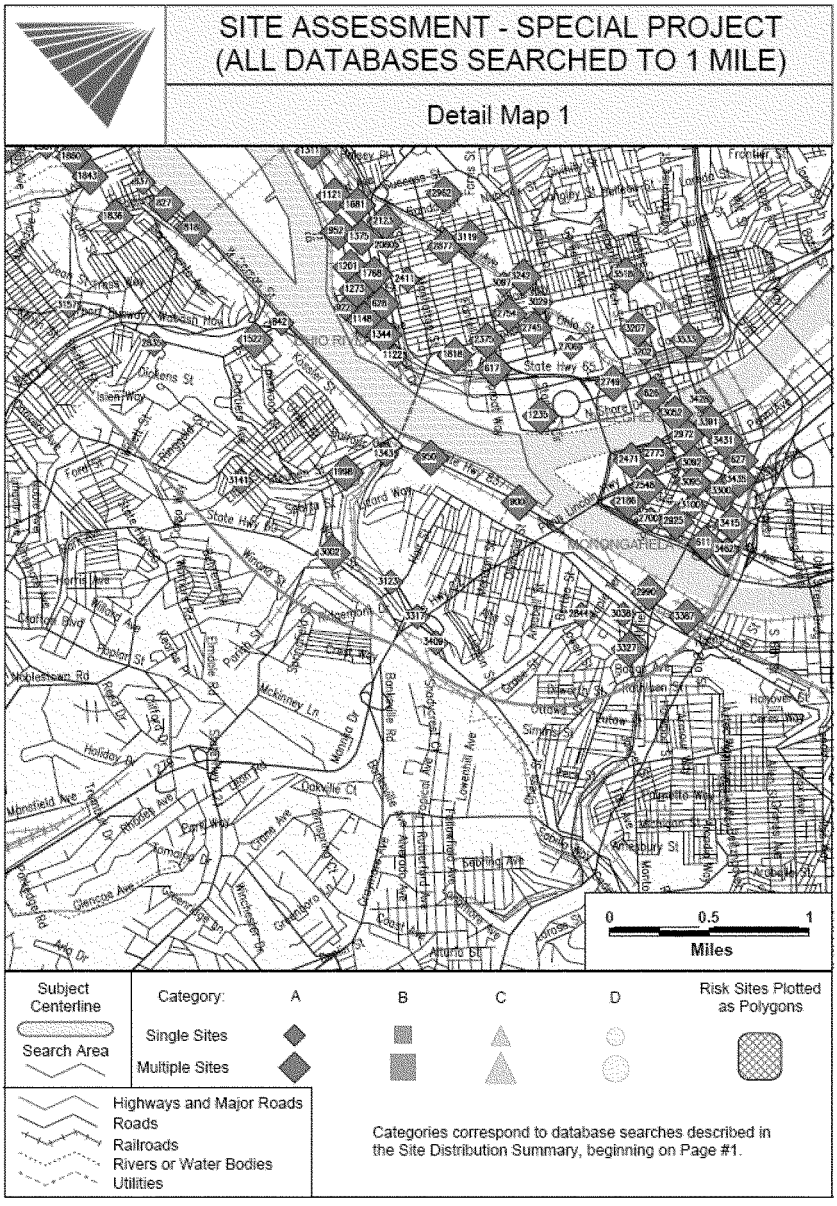
N
W E
S

Categories correspond to database searches described in the Site Distribution Summary, beginning on Page #1.

For More Information Call VISTA Information Solutions, Inc. at **1 - 800 - 767 - 0403**
Report ID: **436489001** Date of Report: **October 25, 2001**



For More Information Call VISTA Information Solutions, Inc. at 1 - 800 - 767 - 0403
Report ID: 436489001 Date of Report: October 25, 2001



For More Information Call VISTA Information Solutions, Inc. at 1 - 800 - 767 - 0403
Report ID: 436489001 Date of Report: October 25, 2001

Incident Reports for Site 950 (page 1 of 3)

VISTA Address*:	1686 W KARSON PITTSBURGH, PA 0	VISTA ID#:	66130614
		Distance/Direction:	0.06 MI / E
		Plotted as:	Point
ERNS - Emergency Response Notification System / SRC# 8		Agency ID:	530590

Agency Address:	SAME AS ABOVE
NRC Report #:	530590
Location	1686 W KARSON PITTSBURGH PA
County:	ALLEGHENY
Discharger Last Name:	UNKNOWN
Discharger Company	GUTMAN OIL
Discharger Organization Type	PRIVATE ENTERPRISE
Discharger Address	1686 WEST KARSON PITTSBURGH PA
Discharger Phone #	4122552935
Date/Time Reported:	30-MAY-00
Date/Time Completed:	30-MAY-00
Call Taker:	JLC3759
Cause of Incident:	UNKNOWN
Date/Time of Incident:	30-MAY-00
Description of Incident:	COMPLAINT OF DIESEL FUEL SPILL AT A GAS STATION
Incident Type:	FIXED
Air Release:	NO
Land Release:	NO
Water Release:	YES
Ground Release:	NO
Facility Release:	NO
Other Release:	NO
Media Affected	WATER
Source:	UNAVAILABLE
Comments	REFUSHALLED MATERIAL INVESTIGATION UNDERWAY
CAS #:	000000-00-0
CHRIS Code:	OTD

Material Spilled:	OIL, FUEL NO. 2-D
Material Quantity:	#
Unit Of Measuere:	GALLONS
Fields Not Reported by the Source Agency for this Site:	Name(1), Location I(1), Location II(1), Location III(1), Discharger Last Name(1), Discharger Secondary Address(1), Additional Medium Information(1)

Incident Reports for Site 950 (page 2 of 3)

MSTA Address*:	WEST CARSON STREET EXXON 1686 W CARSON ST PITTSBURGH, PA 15219	VISTA ID#:	2418934
		Distance/Direction:	0.06 MI / E
		Plotted as:	Point
STATE UST - State Underground Storage Tank / SRC# 450		EPA/Agency ID:	N/A

Agency Address:	SAME AS ABOVE
Facility Name:	WEST CARSON STREET EXXON
Facility Address:	1686 W CARSON ST PITTSBURGH, PA 15219
Facility ID #:	02-03574
Total Underground Tanks:	5
Total Aboveground Tanks:	NOT REPORTED
Total Tanks Removed:	NOT REPORTED
Owner ID #:	21838
Owner Name:	GUTMAN OIL CO
Owner Address:	200 SPHERS ST BELLE VERNON, PA 15012
Owner Phone #:	6372448335
Tank ID #:	952
Tank Sequence:	001
Tank Installation Date:	19781201
Tank Capacity (G):	00008000
Tank Contents:	DIESEL
Tank Status:	CURRENTLY IN USE
Tank ID #:	953
Tank Sequence:	002
Tank Installation Date:	19811201
Tank Capacity (G):	00008000
Tank Contents:	GASOLINE
Tank Status:	CURRENTLY IN USE
Tank ID #:	954
Tank Sequence:	003
Tank Installation Date:	19781201
Tank Capacity (G):	00010000
Tank Contents:	DIESEL
Tank Status:	CURRENTLY IN USE
Tank ID #:	955
Tank Sequence:	004
Tank Installation Date:	19811201
Tank Capacity (G):	00010000

Incident Reports for Site 950 (page 3 of 3)

Tank Contents:	GASOLINE
Tank Status:	CURRENTLY IN USE
Tank ID #:	956
Tank Sequence:	005
Tank Installation Date:	19811201
Tank Capacity (G):	00010000
Tank Contents:	GASOLINE
Tank Status:	CURRENTLY IN USE
Fields Not Reported by the Source Agency for this Site:	Facility Secondary Address(1)

STATE LUST - State Leaking Underground Storage Tank / SRC# 453	EPA/Agency ID:	N/A

Agency Address:	WEST CARSON STREET EXXON 1686 W CARSON ST PITSBURGH, PA 0
Site Name:	WEST CARSON STREET EXXON
Site Address:	1686 W CARSON ST
Site City:	PITSBURGH
Site State:	PA
Site County:	ALLEGHENY
Site Region:	SOUTHWEST
Class:	CLEANUP OF UNDERGROUND STORAGE TANKS AT FEDERALLY REGULATED PETROLEUM FACILITIES
Substance Leaked:	LEADED GASOLINE
Media Affected:	NOT REPORTED
Discovery Date:	NOT REPORTED
Class:	CLEANUP OF UNDERGROUND STORAGE TANKS AT FEDERALLY REGULATED PETROLEUM FACILITIES
Date Closed	2/16/96
Substance Leaked:	UNLEADED GASOLINE
Media Affected:	NOT REPORTED
Discovery Date:	NOT REPORTED
Fields Not Reported by the Source Agency for this Site:	Date Closed(1)

SUPPLEMENT 8-B

EXAMPLE OF RECREATIONAL BOATING ACCIDENT REPORT DATABASE

(BARD)

2001

State	Name of Body of Water	County	Nearest City or Town	Location	Accident Report No#	Date	Time
IL	Bangs Lake	Lake	Wauconda		2001-IL-0101	09/02/2001	11:32 AM
IL	Bangs Lake	Lake	Wauconda	Wauconda park dist.	2001-IL-0074	07/22/2001	10:06 AM
IL	Calumet River	Cook	Chicago	5/8 on Cal River under 130th bridge	2001-IL-0021	06/10/2001	5:30 PM
IL	Carlyle Lake	Clinton	Boulder	Boulder Marina	2001-IL-0013	05/19/2001	7:15 AM
IL	Carlyle Lake	Clinton	Carlyle	Dam East Boat Ramp	2001-IL-0014	05/19/2001	4:15 PM
IL	Carlyle Lake	Clinton	Carlyle		2001-IL-0069	10/20/2001	5:15 PM
IL	Carlyle Lake	Clinton	Keyesport	1/2 mile northeast of Keyesport boat ramp	2001-IL-0112	11/30/2001	6:45 AM
IL	Carlyle Lake	Clinton	Carlyle	Between Pooint 1 and Eldon Hazlet Campground	2001-IL-0025	06/12/2001	3:00 PM
IL	Carlyle Lake	Clinton	Boulder	Island north of Boulder Marina	2001-IL-0055	07/01/2001	10:00 AM
IL	Carlyle Lake	Clinton	Keyesport	Harbor Light Bay - Private Boat Dock	2001-IL-0087	08/12/2001	1:30 PM
IL	Chicago River	Cook	Chicago	about 31st St. Lowest bridge	2001-IL-0109	10/18/2001	1:00 AM
IL	Chicago River	Cook	Chicago	Lake Michigan Locks	2001-IL-0091	01/22/2001	
IL	Chicago Sanitary and Ship Cana	Cook	Lemont	Egan Marine Corp. barge repair ship	2001-IL-0108	10/17/2001	6:00 PM
IL	Clinton Lake	DeWitt	Clinton	Hot water discharge area	2001-IL-0006	04/29/2001	3:30 PM
IL	Clinton Lake	Dewitt	Clinton	Houseboat Cove	2001-IL-0020	06/09/2001	7:00 PM
IL	Clinton Lake	DeWitt	Lane	Peninsula Day Use Area	2001-IL-0102	09/03/2001	5:25 PM
IL	Clinton Lake	DeWitt	Fullerton	Rt. 48 Bridge	2001-IL-0103	09/03/2001	4:00 PM
IL	Clinton Lake	Dewitt	Lane	1 mile southwest marina	2001-IL-0023	06/10/2001	11:30 AM

IL	Des Plaines River	Will	Channahon	mile marker 282	2001-IL-0036	06/17/2001	7:30 PM
IL	Des Plaines River	DuPage	Burr Ridge	Madison and Jeans	2001-IL-0082	10/13/2001	6:30 PM
IL	Forbes State Park Lake	Marion	Omego, IL		2001-IL-0007	05/05/2001	1:30 PM
IL	Fox Lake	Lake	Lake Villa	Columbia Bay	2001-IL-0068	09/30/2001	4:29 PM
IL	Fox Lake	Lake	Fox Lake	Mineola Bay, 200 yards off of Mineola Marina	2001-IL-0065	09/22/2001	8:57 PM
IL	Fox River	McHenry	Cary	North of Rt. 14 & west of the county line	2001-IL-0092	09/22/2001	8:40 PM
IL	Fox River	McHenry	Cary	1/4 mi. north of Rawson Bridge Rd.	2001-IL-0010	05/04/2001	1:30 PM
IL	Fox River	McHenry	Island Lake	1 mi. so. of Rt. 176	2001-IL-0009	05/20/2001	4:45 PM
IL	Fox River	Kane			2001-IL-0107	09/08/2001	2:00 PM
IL	Governor Bond Lake	Bond	Greenville	200 yards Southwest of Ski Club boat dock	2001-IL-0041	06/22/2001	1:30 PM
IL	Grass Lake	Lake	Antioch	South of Grass Lake Rd.	2001-IL-0079	07/29/2001	2:30 AM
IL	Holiday Shores Lake	Madison	Edwardsville	Near dam	2001-IL-0059	07/04/2001	2:38 PM

139	OH
120	IN
15	WV
71	KY
80	PA
108	IL
533	

FOR CONTINUATION OF HOUSE DOCUMENT 115-22

UPPER OHIO NAVIGATION STUDY, PA FINAL FEASIBILITY REPORT
AND INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

SEE PART 6