LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

COMMUNICATION

FROM

THE PRESIDENT OF THE UNITED STATES

TRANSMITTING

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

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DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

OCT 14 2014

Honorable John Boehner
Speaker of the House
of Representatives
U.S. Capitol Building, Room H-232
Washington, DC 20515-0001

Dear Mr. Speaker:

In response to a study resolution adopted on May 6, 1998, by the Committee on Transportation and Infrastructure of the U.S. House of Representatives, the Secretary of the Army recommends the Lynnhaven River Basin Ecosystem Restoration Project, Virginia. The proposal is described in the report of the Chief of Engineers, dated March 27, 2014, which includes other pertinent reports and comments. The report contains an Environmental Assessment and a Finding of No Significant Impact. The views of the Commonwealth of Virginia are set forth in the enclosed communication. The project was authorized in section 7002(5)10 of the Water Resources Reform and Development Act of 2014. The Secretary of the Army plans to implement the project at the appropriate time, considering National priorities and the availability of funds.

The recommended plan would restore approximately 38 acres of wetlands, 94 acres of submerged aquatic vegetation (SAV), reintroduce the bay scallop on 22 acres of the restored SAV, and construct 31 acres of artificial reef habitat on 24 sites within a 64 square mile tidal estuary within the City of Virginia Beach, Virginia. The project would provide habitat for 5 Federal endangered species, including the hawksbill, Kemp's Ridley and leatherback sea turtles and the roseate tern; 4 additional state endangered species including the eastern chicken turtle, Wilson's plover, Rafinesque's big-eared bat, and the canebrake rattlesnake; and essential fish habitats for 19 species of fin fish.

The estimated project first cost of the recommended plan is $35,656,000 based on October 2014 price levels. In accordance with the cost sharing provision of section 103 of the Water Resources Development Act of 1986, as amended, the Federal share of the first costs would be about $23,176,400 (65 percent) and the non-Federal share would be about $12,479,600 (35 percent). However, I have determined that the re-introduction of the bay scallop, while it would be an important recreational or commercial endeavor, should more appropriately be undertaken by another agency. Thus, project first cost of the plan that I support is $34,963,000, to be cost shared $22,726,000 and $12,237,000.

Based on a discount rate of 3.375 percent and a 50-year period of economic analysis, the total equivalent average annual costs of the project are estimated to be $1,491,000, including operation, maintenance, repair, replacement and rehabilitation

(OMRR&R). The cost of the recommended restoration features is justified by increasing species diversity, increasing secondary production and increasing marsh productivity. The costs of lands, easements, rights-of-way, relocations, and dredged or excavated material disposal (LERRD) areas are estimated at $752,000. The City of Virginia Beach would be the non-Federal sponsor responsible for OMRR&R of the project after construction, at an estimated average annual cost of $2,000.

The Office of Management and Budget (OMB) advises that there is no objection to the submission of the report to Congress and concludes that the report recommendation is consistent with the policy and programs of the President. OMB also noted that the project would need to compete with other proposed investments for funding in future budgets. A copy of OMB's letter, dated October 6, 2014, is enclosed. I am providing a copy of this transmittal and the OMB letter to the Subcommittee on Water Resources and Environment of the House Committee on Transportation and Infrastructure, and the Subcommittee on Energy and Water Development of the House Committee on Appropriations. I am also sending an identical letter to the President of the Senate.

Very truly yours,

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

Enclosures

5 Enclosures

1. Report of the Chief of Engineers, Mar 27, 2014
2. OMB Letter, Oct 06, 2014
3. Commonwealth of Virginia Letter, Nov 13, 2013
4. HQUSACE Letter, Mar 06, 2014
5. Final Report – Lynnhaven River Basin Ecosystem Restoration Project Report and Environmental Assessment, Jul 2013, modified Feb 14 (DVD)

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

DAEN

MAR 27 2014

SUBJECT: Lynnhaven River Basin Ecosystem Restoration Project, Virginia

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on ecosystem restoration in the Lynnhaven River Basin, Virginia. It is accompanied by the report of the district and division engineers. These reports are an interim response to a resolution by the Committee on Transportation and Infrastructure of the United States House of Representatives, Docket 2558, adopted May 1998. The resolution requested the review of the report of the Chief of Engineers on the Lynnhaven Inlet, Bay, and Connecting Waters, Virginia, published as House Document 580, 80th Congress, 2nd Session, and other pertinent reports to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of environmental restoration and protection and other related water resources purposes for the Lynnhaven River Basin, Virginia. Preconstruction, engineering, and design activities for the Lynnhaven River Basin Ecosystem Restoration Project will continue under the authority provided by the resolution cited above.

2. The Lynnhaven River Basin, the southernmost tributary to the Chesapeake Bay in Virginia, is a 64 square mile tidal estuary in the lower Chesapeake Bay Watershed. The Lynnhaven River's three branches, the Eastern, Western, and the Broad Bay/Linkhorn Bay, represent approximately 0.4 percent of the area of Virginia and approximately 0.2 percent of the Chesapeake Bay Watershed. However, the basin encompasses one-fourth of the area of the city of Virginia Beach and provides vital functions to the city and its residents. As has happened throughout the Chesapeake Bay, the Lynnhaven River Basin has seen declines in essential habitat - submerged aquatic vegetation (SAV), wetlands, oysters and scallops - and an overall reduced water quality from alterations to the ecosystem primarily stemming from increased development and population.

3. The significance of this ecosystem is demonstrated on the national, regional, and local level. Five federal and state endangered species occur or potentially occur in the Lynnhaven River Basin, including the hawksbill, Kemp's Ridley and leatherback sea turtles and the roseate tern. Also within the basin there are four additional state endangered species to include the eastern chicken turtle, Wilson's plover, Rafinesque's big-eared bat, and the canebrake rattlesnake. The Lynnhaven River Basin includes essential fish habitats for 19 species of fin fish, which demonstrates the important of estuaries as rearing grounds not only for fin fish sought by commercial and recreational fishermen, but for shell fish as well. During 2012, more than 149,000 pounds of fin fish, 369,000 pounds of blue crabs, 2,400 pounds of conch and 18,500 pounds of hard shell clams were landed in the Lynnhaven River Basin with an approximate value

of $1 million. In 1983, 1987 and 2000, the states of Virginia, Maryland, and Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and the U.S. Environmental Protection Agency (EPA), representing the federal government, signed historic agreements establishing the Chesapeake Bay Program, a strong partnership to protect and restore the Chesapeake Bay ecosystem. In addition, Section 704(b) of the Water Resources Development Act (WRDA) of 1986, as amended through Section 505 of the WRDA of 1996; the re-authorization of Section 704(b); Section 342 of the WRDA of 2000; and the Section 704(b) as amended by Section 5021 of WRDA 2007 provided for the restoration of oysters within the Chesapeake Bay and its tributaries. Recently, all of the laws and agreements affecting the restoration, protection, and conservation of the Chesapeake Bay have been brought into focus under the Chesapeake Bay Protection and Restoration Executive Order (EO 13508) signed by President Barack Obama on 12 May 2009. Locally, the city of Virginia Beach, The Trust for Public Land, and the Chesapeake Bay Foundation have partnered to purchase and protect 122 acres of natural lands known as Pleasure House Point, one of the largest undeveloped tracts of land on the Lynnhaven River.

4. The reporting officers recommend authorization of a plan to restore approximately 38 acres of wetlands, 94 acres of SAV, reintroduction of the bay scallop on 22 acres of the restored SAV, and construction of 31 acres of artificial reef habitat. The restoration measures, at various sites throughout the basin, will significantly increase three types of habitats, at least two of which are an essential part of the food web for several of the endangered species and form the basis of many of the essential fish habitats. The recommended plan is the National Ecosystem Restoration (NER) Plan. Implementation of the recommended plan will have substantial beneficial impact on the biological integrity, habitat diversity, and resiliency of the Lynnhaven River Basin.

5. Based on an October 2013 FY14 price level, the estimated project first cost of the NER Plan is $35,110,000, which includes a 10-year monitoring and adaptive management program at an estimated cost of $1,750,000, developed to adequately address the uncertainties inherent in a large environmental restoration project and to improve the overall performance of the project. In accordance with the cost sharing provisions contained in Section 103(c) of the WRDA 1986, as amended (33 U.S.C. 2213(c)), ecosystem restoration features are cost-shared at a rate of 65 percent federal and 35 percent non-federal. Thus the federal share of the project first cost is $22,821,500 and the non-federal share is estimated at $12,288,500, which includes the costs of land, easements, rights-of-way, relocations, and dredged or excavated material disposal areas (LERRD) estimated at $740,000. The non-federal sponsor will receive credit for the costs of LERRD toward the non-federal share. The City of Virginia Beach is the non-federal cost-sharing sponsor for the recommended plan. The city would be responsible for the operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) of the project after construction, an average annual cost currently estimated at $2,000.

6. Based on a 3.5 percent discount rate and a 50-year period of analysis, the total equivalent average annual costs of the project are estimated to be $1,554,000, including monitoring estimated at $30,000 and $2,000 for OMRR&R. All project costs are allocated to the authorized purpose of ecosystem restoration and are justified by an increase in species diversity (measured

using a biological index), an increase in secondary production, and an increase in marsh productivity (an average increase of 70 points using the EPA Marsh Assessment Score). The plan would improve essential estuarine habitats in the most cost-effective and sustainable manner.

7. The recommended plan was developed in coordination and consultation with various federal, state, and local agencies using our cost effectiveness and incremental cost analysis techniques to formulate ecosystem restoration solutions and evaluate the impacts and benefits of those solutions. Plan formulation evaluated a wide range of non-structural and structural alternatives under Corps policy and guidelines as well as consideration of a variety of economic, social, and environmental goals. The recommended plan delivers a sustainable approach to solve water resources and ecosystem challenges while contributing towards the goals of the EO 13508 strategy to restore tidal wetlands, enhance degraded wetlands, sustain fish and wildlife by restoring oyster habitat in a tributary of the Chesapeake Bay, and restore priority habitat such as submerged aquatic vegetation.

8. In accordance with the Corps Engineering Circular on sea level change (SLC), three sea level rise rates; a baseline estimate representing the minimum expected SLC, an intermediate estimate, and a high estimate representing the maximum expected SLC were analyzed during the study. Projecting the three rates over the 50-year period provides a predicted low level rise of 0.73 feet (ft), an intermediate level rise of 1.14ft, and a high level rise of 2.48ft. The project is designed based upon the historical, or minimum rate of SLC. The two elements of the project that would be most impacted by SLC are the SAV and wetland restoration, while SLC would have little or no effect on the reef habitat or scallop restoration. Marshes within the Lynnhaven basin have historically sustained themselves from the effect of SLC through vertical accretion, although migration landward is a possibility. Similarly, as the water column becomes deeper due to SLC, the SAV will migrate into shallow waters if allowed by the geography and development of the inundated shoreline. Because a large amount of the Lynnhaven shoreline is developed, the ability of the SAV and marshes to adjust to SLC may be limited.

9. In accordance with Corps Engineering Circular on review of decision documents, all technical, engineering, and scientific work underwent an open, dynamic, and vigorous review process to ensure technical quality. This included District Quality Control, Agency Technical Review (ATR) - coordinated by the Ecosystem Restoration Planning Center of Expertise (ECO-PCX), policy and Legal Compliance Review, Cost Engineering Directory of Expertise Review and Certification, and Model Review and Approval. All concerns of the ATR have been addressed and incorporated in the final report. Given the nature of the project, an exclusion from the requirement to conduct Type I Independent Peer Review was granted on 31 July 2013. Concerns expressed by the ECO-PCX team have been addressed and incorporated in the final report.

10. Washington level review indicates the plan recommended by the reporting officers is technically sound, environmentally and socially acceptable, and on the basis of Congressional directives, economically justified. The plan complies with all essential elements of the U.S. Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for

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Water and Land Related Resources Implementation Studies. The recommended plan complies with other administration and legislative policies and guidelines. The views of interested parties, including federal, state, and local agencies, have been considered. State and agency comments received during review of the final report and environmental assessment were addressed. The EPA inquired whether information on sea level rise from another study in the area was considered. The Commonwealth of Virginia expressed concern regarding whether the required leases would be able to be obtained expeditiously; summarized prior coordination with and commitments to Virginia's regulatory and resource agencies; and made recommendations concerning project methods.

11. I concur with the findings, conclusions, and recommendations of the reporting officers. Accordingly, I recommend that the plan for ecosystem restoration in the Lynnhaven River Basin, Virginia be authorized in accordance with the reporting officers' recommended plan at an estimated cost of $35,110,000 with such modifications as in the discretion of the Chief of Engineers may be advisable. My recommendation is subject to cost sharing, financing, and other applicable requirements of federal and state laws and policies, including Section 103 of WRDA 1986, as amended (33 U.S.C. 2213). Accordingly, the non-federal sponsor must agree with the following requirements prior to project implementation.

a. Provide 35 percent of total ecosystem restoration costs as further specified below:

(1) Provide 35 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

(2) Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements desired on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material as determined by the government to be required or to be necessary for the construction, operation, and maintenance of the project;

(3) Provide, during construction, any additional funds necessary to make its total contribution equal to 35 percent of total project costs.

b. Prior to initiation of construction, obtain approval from the Commonwealth of Virginia of an administrative designation in perpetuity for the river bottom areas required for the artificial reef and aquatic vegetation features of the project that provides sufficient protection to those areas from uses incompatible with the project;

c. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

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d. Shall not use project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project;

e. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 Code of Federal Regulations Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

f. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations and any specific directions prescribed by the federal government;

g. Hold and save the United States free from all damages arising from the design, construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors.

h. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under the lands, easements, or rights-of-way that the federal government determines to be required for construction, operation, and maintenance of the project. However, for lands that the federal government determines to be subject to the navigation servitude, only the federal government shall perform such investigation unless the federal government provides the non-federal sponsor with prior specific written direction, in which case the non-federal sponsor shall perform such investigations in accordance with such written direction;

i. Assume, as between the federal government and the non-federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction or operation and maintenance of the project;

j. Agree, as between the federal government and the non-federal sponsor, that the non-federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA.

12. The recommendation contained herein reflects the information available at this time and current departmental policies governing the formulation of individual projects. It does not reflect

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program and budgeting priorities inherent in the formulation of a national civil works construction program or the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to Congress as a proposal for authorization and implementation funding. However, prior to transmittal to Congress, the City of Virginia Beach, Virginia (the non-federal sponsor), the state, interested federal agencies, and other parties will be advised of any significant modifications and will be afforded an opportunity to comment further.

THOMAS P. BOSTICK
Lieutenant General, USA
Chief of Engineers

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

October 6, 2014

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, DC 20310-0108

Dear Ms. Darcy:

As required by Executive Order 12322, the Office of Management and Budget (OMB) has completed its review of your recommendation for the Lynnhaven River Basin Ecosystem Restoration Project in Virginia Beach, Virginia, with a first cost of $35,110,000 (October 2013 price level).

The Administration supports efforts to protect and restore Chesapeake Bay resources. Through the proposed project, the Corps would partner with the City of Virginia Beach to restore ecological resources in the Lynnhaven River Basin, the southernmost tributary of the Chesapeake Bay. The Corps proposes to construct a variety of habitats—wetlands, oyster reefs, and submerged aquatic vegetation (SAV)—and reintroduce bay scallops into the river basin. The habitats constructed are expected to serve as foraging, feeding, nursery, and nesting habitat for a variety of aquatic and avian species, including several species listed under the Endangered Species Act (e.g., the hawksbill, Kemp's Ridley and leatherback sea turtles and the roseate tern). Additionally, the recommended project would provide essential fish habitat for 19 fin fish species.

We agree with your recommendation that the reintroduction of the bay scallop is outside of the scope of the Corps' aquatic ecosystem restoration program. Without scallop reintroduction, this project would have a total first cost of $34,427,000.

The Office of Management and Budget does not object to you submitting this report to Congress. When you do so, please advise the Congress that the project—with the exception of the scallop reintroduction component—is consistent with the programs and policies of the President. In addition, please advise the Congress that the project would need to compete with other proposed investments for funding in future budgets.

Sincerely,

John Pasquantino
Deputy Associate Director
Energy, Science, and Water

COMMONWEALTH of VIRGINIA

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Douglas W. Domenech
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November 13, 2013

Headquarters
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3860

RE: Final Feasibility Report and Integrated Environmental Assessment for the Lynnhaven River Basin Ecosystem Restoration, City of Virginia Beach, U.S. Army Corps of Engineers, DEQ 13-182F.

Dear Sir or Madam:

The Commonwealth of Virginia has completed its review of the above-referenced document. The Department of Environmental Quality is responsible for coordinating Virginia's review of federal environmental documents submitted under the National Environmental Policy Act (NEPA) and responding to appropriate federal officials on behalf of the Commonwealth. DEQ is also responsible for coordinating Virginia's review of federal consistency documents submitted pursuant to the Coastal Zone Management Act (CZMA) and providing the state's response. The Commonwealth responded to the Federal Consistency Determination submitted for this project on October 10, 2013 (DEQ 13-157F). The following agencies and planning district commission joined in this review:

Department of Environmental Quality
Department of Conservation and Recreation
Department of Health
Virginia Marine Resources Commission
Hampton Roads Planning District Commission

In addition, the Department of Game and Inland Fisheries, Department of Historic Resources, and the City of Virginia Beach were invited to comment on the proposal.

PROJECT DESCRIPTION

The U.S. Army Corps of Engineers (Corps) proposes to conduct an ecosystem restoration project in the Lynnhaven River in the City of Virginia Beach. The project includes four elements:

1) Ninety-four acres in the main stem and Broad Bay will be seeded to produce submerged aquatic vegetation (SAV) habitat.
2) When the SAV becomes established, bay scallops will be grown on site to build a self-sustaining population.
3) Hard reef structures will be placed in Broad Bay and Lynnhaven Bay through the placement of reefs.
4) Restoration efforts will occur at four wetland sites.

The Corps has submitted a Final Feasibility Report and Integrated Environmental Assessment for review and comment under the National Environmental Policy Act and the Corps' water resources planning process and requirements.

CONCLUSION

Provided activities are performed in accordance with the recommendations which follow in the Impacts and Mitigation section of this report, this proposal is unlikely to have significant effects on ambient air quality, water quality, wetlands, important farmland, forest resources, and historic resources. It is unlikely to adversely affect species of plants or insects listed by state agencies as rare, threatened, or endangered.

As discussed in VMRC's May 24, 2013 letter to the Norfolk District of the Corps (attached), proposed project activities may conflict with current shellfish lease activities (i.e. coastal uses) in the Lynnhaven basin, as most of the lower Lynnhaven is currently leased for commercial shellfish production. In addition, the proposed establishment of submerged aquatic vegetation and scallops in identified areas may limit existing shellfish aquaculture activities as well as public access to areas within the Lynnhaven watershed. Accordingly, during the Joint Permit Application (JPA) review process, proposed project impacts to existing leases will require a notification to the leaseholder(s) of record and confirmation that they agree with the proposed activity on their leases. The benefits and detriments of the proposed activities will be weighed by VMRC before a permit decision is reached.

ENVIRONMENTAL IMPACTS AND MITIGATION

1. Surface Waters and Wetlands. According to the EA (page 218), temporary, minor increases in turbidity, dissolved solids, and dissolved nutrients may result from the resuspension of bottom sediments during the placement of fish reefs and mats. Sediment from the salt marsh sites will be exposed during the restoration process and could enter the water column. Increased turbidity has the potential to lower dissolved oxygen. Construction activities will be short-term in nature, so conditions should return to pre-construction levels quickly after the project has been completed. Best management practices (BMPs) will be implemented while the wetland sites are being restored and the areas will be revegetated in order to eliminate adverse water quality impacts.

The EA (page 207) states that three elements of the recommended plan, SAV planting, reef habitat installation, and Bay Scallops, will have no impact on wetlands. The fourth major part of the Lynnhaven Project involves the restoration of four wetlands. All the restoration areas are included in the U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (NWI). The modifications to the wetland sites will be completed through physical alteration of the existing topography and application of herbicides. These actions may result in short-term impacts such as exposure of marsh sediment, damage to native wetland plants currently at the site, and mortality of sessile or slow moving organisms that inhabit the project area. The long-term impacts of wetland restoration will be positive in nature.

1(a) Agency Jurisdiction.

(i) Department of Environmental Quality

The State Water Control Board (SWCB) promulgates Virginia's water regulations, covering a variety of permits to include Virginia Pollutant Discharge Elimination System Permit, Virginia Pollution Abatement Permit, Surface and Groundwater Withdrawal Permit, and the Virginia Water Protection Permit (VWPP). The VWPP is a state permit which governs wetlands, surface water, and surface water withdrawals/impoundments. It also serves as § 401 certification of the federal *Clean Water Act* § 404 permits for dredge and fill activities in waters of the U.S. The VWPP Program is under the Office of Wetlands and Water Protection/Compliance, within the DEQ Division of Water Quality Programs. In addition to central office staff that review and issue VWP permits for transportation and water withdrawal projects, the six DEQ regional offices perform permit application reviews and issue permits for the covered activities.

(ii) Virginia Marine Resources Commission

The Virginia Marine Resources Commission (VMRC) issues permits for tidal wetlands impacts in accordance with Subtitle III of Title 28.2 of the Code of Virginia. The permit review process takes into account various local state and federal statutes governing the disturbance or alteration of environmental resources. Applications may receive independent yet concurrent review by local wetland boards.

1(b) Agency Findings.

(i) Department of Environmental Quality

The VWPP program at DEQ's Tidewater Regional Office (DEQ-TRO) finds that many of the individual components of the restoration plan will impact surface waters (including wetlands).

(ii) Virginia Marine Resources Commission

According to VMRC, the Virginia Beach Wetlands Board will not need to review and issue a permit for the project, provided wetland restoration activities and impacts occur on city-owned or leased wetlands. However, VMRC believes it is likely the project elements could change based on the public interest review required for any permits needed for the use of tidal wetlands.

1(c) Recommendations. The project must comply with section 404 (b)(1) guidelines of the Clean Water Act and with the Commonwealth's wetlands mitigation policies. Both federal and state guidelines recommend avoidance and minimization of wetlands impacts as the first steps in the mitigation process. To minimize unavoidable impacts to wetlands and waterways, DEQ recommends the following practices:

- Operate machinery and construction vehicles outside of stream-beds and wetlands; use synthetic mats when in-stream work is unavoidable.
- Preserve the top 12 inches of trench material removed from wetlands for use as wetland seed and root-stock in the excavated area.
- Design erosion and sedimentation controls in accordance with the most current edition of the Virginia Erosion and Sediment Control Handbook. These controls should be in place prior to clearing and grading, and maintained in good working order to minimize impacts to State waters. The controls should remain in place until the area is stabilized.
- Place heavy equipment, located in temporarily impacted wetland areas, on mats, geotextile fabric, or use other suitable measures to minimize soil disturbance, to the maximum extent practicable.
- Restore all temporarily disturbed wetland areas to pre-construction conditions and plant or seed with appropriate wetlands vegetation in accordance with the cover type (emergent, scrub-shrub, or forested). The applicant should take all appropriate measures to promote revegetation of these areas. Stabilization and restoration efforts should occur immediately after the temporary disturbance of each wetland area instead of waiting until the entire project has been completed.
- Place all materials which are temporarily stockpiled in wetlands, designated for use for the immediate stabilization of wetlands, on mats, geotextile fabric in order to prevent entry in State waters. These materials should be managed in a manner that prevents leachates from entering state waters and must be entirely removed within thirty days following completion of that construction activity. The disturbed areas should be returned to their original contours, stabilized within

thirty days following removal of the stockpile, and restored to the original vegetated state.

- Flag or clearly mark all non-impacted surface waters within the project or right-of-way limits that are within 50 feet of any clearing, grading, or filling activities for the life of the construction activity within that area. The project proponent should notify all contractors that these marked areas are surface waters where no activities are to occur.
- Employ measures to prevent spills of fuels or lubricants into state waters.

The Corps should work closely with the Wetlands Board staff to ensure that the proposal qualifies for a local exemption.

1(d) Requirements. The initiation of the VWPP review process is accomplished through the submission of a Joint Permit Application (JPA) (form MRC 30-300) to the VMRC. Upon receipt of a JPA for the proposed surface waters impacts, VWPP staff at DEQ-TRO will review the proposed project in accordance with the VWPP regulations and guidance. In addition, any potential jurisdictional impacts to tidal wetlands will be reviewed by VMRC during the JPA review process.

1(e) Conclusion. Provided that a Joint Permit Application is submitted for any proposed surface water and wetland impacts and appropriate city, state, and federal authorization is received and complied with, the restoration efforts will be in compliance with the VWPP and local programs.

2. Subaqueous Lands Impacts. The EA does not discuss permitting for proposed project impacts to state-owned subaqueous lands.

2(a) Agency Jurisdiction. The Virginia Marine Resources Commission, pursuant to Section 28.2-1200 *et seq.* of the *Code of Virginia*, has jurisdiction over any encroachments in, on, or over any state-owned rivers, streams, or creeks in the Commonwealth. Accordingly, any portion of the project involving encroachments channelward of mean low water below the fall line may require a permit.

VMRC serves as the clearinghouse for the JPA used by the:

- U.S. Army Corps of Engineers for issuing permits pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act;
- DEQ for issuance of a Virginia Water Protection Permit;
- VMRC for encroachments on or over state-owned subaqueous beds as well as tidal wetlands; and
- local wetlands board for impacts to wetlands.

2(b) Agency Findings. According to VMRC, any proposal to impact, encroach, fill, or dredge submerged bottomlands must obtain an exemption or permit from the agency.

2(c) Requirements. As mentioned above, the JPA review process includes an agency review to identify potential benefits and detriments to the marine resource and public uses. In addition, a public interest review is undertaken including requests for comments and questions. VMRC believes it is likely the project elements could change based on the public interest review required for any permits needed for encroachments over state-owned submerged lands.

3. Erosion and Sediment Control and Stormwater Management. According to the EA (page 224), an erosion control plan will be created and implemented to control the entry of sediments into the tidal streams and their migration downstream of the work area.

3(a) Agency Jurisdiction. Effective July 1, 2013, the Department of Environmental Quality administers the *Virginia Erosion and Sediment Control Law and Regulations* (*VESCL&R*) and *Virginia Stormwater Management Law and Regulations* (*VSWML&R*). In addition, DEQ is responsible for the issuance, denial, revocation, termination and enforcement of the Virginia Stormwater Management Program (VSMP) General Permit for Stormwater Discharges from Construction Activities related to municipal separate storm sewer systems (MS4s) and construction activities for the control of stormwater discharges from MS4s and land-disturbing activities under the Virginia Stormwater Management Program. Note that these programs were previously administered by the Department of Conservation and Recreation.

3(b) Requirements.

(i) Erosion and Sediment Control and Stormwater Management Plans

According to DEQ, the Corps and its authorized agents conducting regulated land-disturbing activities on private and public lands in the state must comply with the *Virginia Erosion and Sediment Control Law and Regulations* (*VESCL&R*) and *Virginia Stormwater Management Law and Regulations* (*VSWML&R*), including coverage under the general permit for stormwater discharge from construction activities, and other applicable federal nonpoint source pollution mandates (e.g. Clean Water Act-Section 313, federal consistency under the Coastal Zone Management Act). Clearing and grading activities, installation of staging areas, parking lots, roads, buildings, utilities, borrow areas, soil stockpiles, and related land-disturbing activities that result in the total land disturbance of equal to or greater than 10,000 square feet (2,500 square feet in Chesapeake Bay Preservation Areas) would be regulated by *VESCL&R*. Accordingly, the applicant must prepare and implement an erosion and sediment control (ESC) plan to ensure compliance with state law and regulations. The ESC plan is submitted to the DEQ Tidewater Regional Office that serves the area where the project is located for review for compliance. The applicant is ultimately responsible for achieving project compliance through oversight of on-site contractors, regular field inspection, prompt action against non-compliant sites, and other mechanisms consistent with agency policy. [Reference: VESCL 62.1-44.15 *et seq.*]

(ii) Virginia Stormwater Management Program General Permit for Stormwater Discharges from Construction Activities

The portions of the project requiring VWPP permitting from DEQ or Section 404 Clean Water Act permitting from the Corps are not required to obtain VSMP permitting for stormwater discharges from construction activities. For any portions of the project not covered under the aforementioned permits, the operator or owner of a construction project involving land-disturbing activities equal to or greater than one acre (2,500 square feet or more in areas analogous to CBPA) is required to register for coverage under the General Permit for Discharges of Stormwater from Construction Activities and develop a project specific stormwater pollution prevention plan (SWPPP). The SWPPP must be prepared prior to submission of the registration statement for coverage under the general permit and the SWPPP must address water quality and quantity in accordance with the VSMP Permit Regulations. General information and registration forms for the General Permit are available on DEQ's website at http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/VSMPPermits/ConstructionGeneralPermit.aspx. [Reference: Virginia Stormwater Management *Act* 62.1-44.15 *et seq.*] VSMP Permit Regulations 9 VAC 25-870-10 *et seq.*].

4. Chesapeake Bay Preservation Areas. The EA does not discuss project impacts to Chesapeake Bay Preservation Areas.

4(a) Agency Jurisdiction. Effective July 1, 2013, the Department of Environmental Quality administers the Chesapeake Bay Preservation Act (Bay Act) (Virginia Code §62.1-44.15 *et seq.*) and *Chesapeake Bay Preservation Area Designation and Management Regulations* (*Regulations*) (9 VAC 50-90-10 *et seq.*). Note that the Bay Act and *Regulations* were previously administered by the Department of Conservation and Recreation.

4(b) Agency Findings. Most of the proposed projects will occur solely upon the subaqueous bottomland of the Lynnhaven River or its tributaries, and are therefore located outside of the jurisdiction of the Chesapeake Bay Preservation Act. There are, however, four wetland restoration projects which will occur within Resource Protection Areas (RPAs). Wetland restoration projects are considered water dependent activities under Section 9 VAC 25-830-140.1 of the *Regulations* and are permitted provided a water quality impact assessment is submitted to DEQ in accordance with Section 9 VAC 25-830-140.6.

5. Air Quality. According to the EA (page 221), the recommended plan would have no long term adverse effects on air quality. Minor, short-term effects on local air quality may occur during construction activities associated with the project. The project is exempt from conducting a conformity determination since estimated emissions from construction equipment would be far below the *de minimis* standards of 100 tons/year, which is the minimum threshold for which a conformity determination must be performed.

5(a) Agency Jurisdiction. DEQ's Division of Air Pollution Control, on behalf of the State Air Pollution Control Board, develops and administers the *State Air Pollution Control Board Regulations for the Control and Abatement of Air* Pollution pursuant to the Air Pollution Control Law. DEQ is charged to carry out mandates of the state law and regulations as well as Virginia's federal obligations under the Clean Air Act as amended in 1990. The objective is to protect and enhance public health and quality of life through control and mitigation of air pollution. The Division ensures the safety and quality of air in Virginia by monitoring and analyzing air quality data, regulating sources of air pollution, and working with local, state and federal agencies to plan and implement strategies to protect Virginia's air quality. The appropriate regional office is directly responsible for issuing necessary permits to construct and operate all stationary sources in the region as well as monitoring emissions from these sources for compliance. As a part of this mandate, environmental documents for new projects to be undertaken in the State are also reviewed. Some projects require additional evaluation under the general conformity provisions of state and federal law.

5(b) Agency Findings. According to the DEQ Air Division, the project site is located in the Hampton Roads ozone (O_3) maintenance area and an emission control area for the contributors to ozone pollution, which are volatile organic compounds (VOCs) and nitrogen oxides (NO_x).

5(c) Recommendation. The Corps should take all reasonable precautions to limit emissions of VOCs and NO_x, principally by controlling or limiting the burning of fossil fuels.

5(d) Requirements.

(i) Fugitive Dust

Fugitive dust must be kept to a minimum by using control methods outlined in 9 VAC 5-50-60 *et seq.* of the *Regulations for the Control and Abatement of Air Pollution.* These precautions include, but are not limited to, the following:

- Use, where possible, of water or chemicals for dust control;
- Installation and use of hoods, fans, and fabric filters to enclose and vent the handling of dusty materials;
- Covering of open equipment for conveying materials; and
- Prompt removal of spilled or tracked dirt or other materials from paved streets and removal of dried sediments resulting from soil erosion.

(ii) Open Burning

If project activities include the open burning or use of special incineration devices for the disposal of debris, this activity must meet the requirements of 9 VAC 5-130-10 through 9 VAC 5-130-60 and 9 VAC 5-130-100 of the *Regulations* for open burning, and it may require a permit. The *Regulations* provide for, but do not require, the local adoption of a model ordinance concerning open burning. The Corps should contact City of Virginia Beach officials to determine what local roquiromonts, if any, exist.

6. Solid and Hazardous Waste Management. According to the EA (page 224), the measures proposed for the Lynnhaven Basin Restoration Project are not expected to result in the identification and/or disturbance of hazardous, toxic or radioactive waste (HTRW). Dredge material that will not be reused on site, but will instead be dewatered and removed to an upland disposal site, is classified as "soil" and is regulated by the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This sediment will be tested as required for proper upland disposal at a landfill facility.

6(a) Agency Jurisdiction. Solid and hazardous wastes in Virginia are regulated by the Virginia Department of Environmental Quality, the Virginia Waste Management Board (VWMB) and the U.S. Environmental Protection Agency. They administer programs created by the federal Resource Conservation and Recovery Act, the Comprehensive Environmental Response Compensation and Liability ("Superfund") Act, and the Virginia Waste Management Act. DEQ administers regulations established by the Waste Management Board and reviews permit applications for completeness and conformance with facility standards and financial assurance requirements. All Virginia localities are required, under the *Solid Waste Management Planning Regulations*, to identify the strategies they will follow on the management of their solid wastes, to include items such as facility siting, long-term (20-year) use, and alternative programs such as materials recycling and composting.

6(b) Agency Comments. The DEQ Division of Land Protection and Revitalization (DLPR) (formerly the Waste Division) finds that the EA addresses solid and hazardous waste issues. DEQ staff conducted a cursory search under zip codes 23459 and 23451, and identified one Superfund site, four Resource Conservation and Recovery Act hazardous waste sites, five Formerly Used Defense Sites (FUDS) and seven petroleum releases. A list of these sites is included in DEQ-DLPR's detailed comments attached to this response.

6(c) Recommendations.

(i) Data Base Search

An environmental investigation at and near the sites selected should be conducted to identify any solid or hazardous waste sites or issues related to the project area. The databases include the Permitted Solid Waste Management Facilities, Virginia Environmental Geographic Information Systems (Solid Waste, Voluntary Remediation Program, and Petroleum Release sites), Comprehensive Environmental Response, Compensation and Liability Act Facilities, and Hazardous Waste Facilities databases. Access to these data bases is discussed in DLPR's detailed comments attached to this response.

(ii) Pollution Prevention

DEQ encourages all projects and facilities to implement pollution prevention principles, including the reduction, reuse, and recycling of all solid wastes generated. All hazardous wastes should be minimized, and managed properly

6(d) Requirements. Material that is suspected of contamination or wastes that are generated must be tested and disposed of in accordance with applicable federal, state, and local laws and regulations. All waste material must be characterized in accordance with the *Virginia Hazardous Waste Management Regulations* prior to disposal at an appropriate facility. It is the generator's responsibility to determine if a solid waste meets the criteria of a hazardous waste which must be appropriately managed.

Questions or requests for further information may be directed to DEQ-LPRD, Steve Coe at (804) 698-4029.

7. Natural Heritage Resources. Natural Heritage Resources are not specifically discussed in the EA.

7(a) Agency Jurisdiction.

(i) Department of Conservation and Recreation

The mission of the Virginia Department of Conservation and Recreation (DCR) is to conserve Virginia's natural and recreational resources. The DCR-Natural Heritage Program's (DCR-DNH) mission is conserving Virginia's biodiversity through inventory, protection, and stewardship. The Virginia Natural Area Preserves Act, 10.1-209 through 217 of the Code of Virginia, was passed in 1989 and codified DCR's powers and duties related to statewide biological inventory: maintaining a statewide database for conservation planning and project review, land protection for the conservation of biodiversity, and the protection and ecological management of natural heritage resources (the habitats of rare, threatened, and endangered species, significant natural communities, geologic sites, and other natural features).

(ii) Department of Agriculture and Consumer Services

The Endangered Plant and Insect Species Act of 1979, Chapter 39, §3.1-102- through 1030 of the *Code of Virginia*, as amended, authorizes the Virginia Department of Agriculture and Consumer Services (VDACS) to conserve, protect and manage endangered species of plants and insects. The VDACS Virginia Endangered Plant and Insect Species Program personnel cooperates with the U.S. Fish and Wildlife Service, DCR-DNH and other agencies and organizations on the recovery, protection or conservation of listed threatened or endangered species and designated plant and insect species that are rare throughout their worldwide ranges. In those instances where recovery plans, developed by the U.S. Fish and Wildlife Service, are available, adherence to the order and tasks outlines in the plans are followed to the extent possible.

7(b) Agency Findings.

***(i)* SAV/Scallop and Reef Habitat Sites**

DCR's Biotics Data System documents the presence of natural heritage resources in the areas of these sites. However, due to the scope of the activity and the distance to the resources, DCR-DNH does not anticipate that these activities will adversely impact identified natural heritage resources.

(ii) Princess Anne, Great Neck North, Mill Dam Creek, and Great Neck South Wetland Restoration/Diversification Sites

DCR supports the efforts to control *Phragmites australis* in the wetland restoration areas. However, DCR has the following concerns with the approach for *Phragmites australis* eradication within the Princess Anne and Great Neck North sites:

1. Excavation of the upper peat layer "in order to remove as much *Phragmites australis* as possible to prevent re-colonization" will likely not remove all *Phragmites* rhizomes. *Phragmites* rhizome penetrates six feet or more into marsh substrate. Rhizomes are very hearty and abundant in a dense stand. Re-sprouting of any remaining rhizome will quickly overcome any new plantings.
2. Such soil disturbance is likely to encourage new *Phragmites* growth from seed or rhizome fragments.
3. Excavation adds the potential for fragments of rhizome to break off and migrate to other areas and establish new stands of *Phragmites.*
4. Removal of the peat will also remove any surviving native seed bank.

In addition, for the Mill Dam Creek and Great Neck South sites, the proposed creation of channels and pools will encourage *Phragmites* growth and the building of upland mounds from excavated material will expand the existing *Phragmites* footprint.

(iii) State-listed Threatened and Endangered Plant and Insect Species

Under a Memorandum of Agreement established between VDACS and DCR, DCR represents VDACS in comments regarding potential impacts on state-listed threatened and endangered plant and insect species. DCR finds that the current activity will not affect any documented state-listed plants or insects.

(iv) State Natural Area Preserves

DCR files do not indicate the presence of any State Natural Area Preserves under the agency's jurisdiction in the project vicinity.

7(c) Recommendations.

(i) Princess Anne, Great Neck North, Mill Dam Creek, and Great Neck South Wetland Restoration/Diversification Sites

DCR recommends three consecutive years of herbicide treatment which is a proven method of controlling *Phragmites*. In addition, soil disturbance should be minimized as much as possible to ensure the native seed bank is available to re-colonize the area. Please see the *Marsh Invader!* brochure (attached) for more details on the control of *Phragmites*.

(ii) Natural Heritage Resources

Contact DCR-DNH to secure updated information on natural heritage resources if a significant amount of time passes before the project is implemented, since new and updated information is continually added to the Biotics Data System.

8. Wildlife Resources and Protected Species. According to the EA (page 215), the recommended plan will have no negative impacts on federally threatened or endangered species or state species of concern. The listed species documented as occurring or potentially occurring in the project area include five sea turtle species, one terrestrial bird, and three shore birds. In addition, an Essential Fish Habitat (EFH) Assessment was completed and submitted to the National Marine Fisheries Service (NMFS). All adverse impacts are determined to be short-term during construction, localized, and minimal.

8(a) Agency Jurisdiction.

(i) Department of Game and Inland Fisheries

The Department of Game and Inland Fisheries (DGIF), as the Commonwealth's wildlife and freshwater fish management agency, exercises enforcement and regulatory jurisdiction over wildlife and freshwater fish, including state or federally listed endangered or threatened species, but excluding listed insects (Virginia Code Title 29.1). The DGIF is a consulting agency under the U.S. Fish and Wildlife Coordination Act (16 U.S.C. sections 661 *et seq.*), and provides environmental analysis of projects or permit applications coordinated through DEQ and several other state and federal agencies. DGIF determines likely impacts upon fish and wildlife resources and habitat, and recommends appropriate measures to avoid, reduce, or compensate for those impacts.

(ii) Department of Health

The Virginia Department of Health's (VDH) Division of Shellfish Sanitation (DSS) is responsible for protecting the health of the consumers of molluscan shellfish and crustacea by ensuring that shellfish growing waters are properly classified for harvesting, and that molluscan shellfish and crustacea processing facilities meet sanitation standards.

8(b) Agency Findings.

(i) Department of Game and Inland Fisheries

DGIF did not respond to DEQ's request for comments on the EA. However, DGIF previously responded to the Federal Consistency Determination submitted by the Corps for the proposal, which was accompanied by the Draft EA for background information. DGIF found that the Draft EA documented a number of federal- and state-listed species from the project area. The Draft EA concluded that the project is not likely to result in adverse impacts upon listed species. However, without detailed information about each proposed project site, DGIF was unable to determine whether listed species may be located at any particular site and vulnerable to adverse impacts.

(ii) Department of Health

VDH-DSS finds that the project includes reef construction and shellfish restoration efforts in waters currently closed to direct shellfish harvest. VDH-DSS would not oppose the project provided that the Corps understands this limitation, and the site(s) can be sufficiently marked and patrolled to prevent illegal harvest.

8(c) Recommendations. DGIF previously recommended that the EA be updated with site-specific information to support the finding that the project is not likely to result in adverse impacts upon listed species. DGIF requested that its staff and the U.S. Fish and Wildlife Service (USFWS) be provided the opportunity to review the information. In addition, DGIF recommended that the EA be updated to reflect the delisting of bald eagles within Virginia and that Virginia no longer maintains a list of "species of concern" and, therefore, no longer designates species as such.

For additional information, contact DGIF, Amy Ewing at (804) 367-2211 and/or VDH-DSS, Keith Skiles at (804) 864-7487.

9. Drinking Water. The EA does not discuss potential project impacts on water supply sources.

9(a) Agency Jurisdiction. The Virginia Department of Health (VDH), Office of Drinking Water (ODW) reviews projects for the potential to impact public drinking water sources (groundwater wells and surface water intakes).

9(b) Agency Findings. VDH-ODW finds that there are no groundwater wells within a 1 mile radius of the project site and no surface water intakes within a five-mile radius. The project is not within Zone 1 (up to 5 miles into the watershed) or Zone 2 (greater than 5 miles into the watershed) of any public surface water sources.

9(c) Conclusion. VDH-ODW concludes that there are no apparent impacts to public drinking water sources due to this project.

For additional information, contact VDH-ODW, Ezekiel Dufore at (804) 864-7201.

10. Historic Structures and Archaeological Resources. According to the EA (page 58), an inventory of sites in the Virginia Department of Historic Resources (DHR) database within a half mile of the potential Lynnhaven River restoration sites resulted in a list of 58 sites, most of which are 20th century houses. No sites were found within the restoration areas themselves although there are two historic sites that are adjacent to restoration areas.

10(a) Agency Jurisdiction. The Department of Historic Resources (DHR) conducts reviews of projects to determine their effect on historic structures or cultural resources under its jurisdiction. DHR, as the designated State's Historic Preservation Office, ensures that federal actions comply with Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended, and its implementing regulation at 36 CFR Part 800. The NHPA requires federal agencies to consider the effects of federal projects on properties that are listed or eligible for listing on the National Register of Historic Places. Section 106 also applies if there are any federal involvements, such as licenses, permits, approvals or funding.

10(b) Requirement. DHR did not respond to DEQ's request for comments on the EA. However, in comments submitted in response to the FCD previously submitted by the Corps for the proposal, DHR noted that the Corps or its agents must consult directly with DHR on individual activities carried out under this initiative as stated in Section 11.11 of the Draft EA, and pursuant to Section 106 of the National Historic Preservation Act (as amended) and its implementing regulations codified at 36 CFR Part 800 which require federal agencies to consider the effects of their undertakings on historic properties.

For additional information, contact DHR, Roger Kirchen at (804) 482-6091.

11. Regional Planning District.

11(a) Jurisdiction. In accordance with the Code of Virginia, Section 15.2-4207, planning district commissions encourage and facilitate local government cooperation and state-local cooperation in addressing, on a regional basis, problems of greater than local significance. The cooperation resulting from this is intended to facilitate the recognition and analysis of regional opportunities and take account of regional influences in planning and implementing public policies and services. Planning district commissions promote the orderly and efficient development of the physical, social and economic elements of the districts by planning, and encouraging and assisting localities to plan, for the future.

11(b) Regional Comments. The Hampton Roads Planning District Commission (HRPDC) reviewed the EA and consulted with the City of Virginia Beach regarding the project. According to the HRPDC, the project appears to be consistent with local and regional plans and policies.

For additional information, contact HRPDC, Dwight Farmer at (757) 420-8300.

REGULATORY AND COORDINATION NEEDS

1. Surface Waters and Wetlands. Proposed wetland and surface water impacts will require authorization through the Virginia Water Protection Permit program pursuant to Virginia Code §62.1-44.15:5. Review under the VWPP program is accomplished through the Joint Permit Application process involving the VMRC, DEQ, Corps, and local wetlands boards. Tidal wetland impacts will require review by the Virginia Beach Wetlands Board. For additional information and coordination regarding the VWPP, contact DEQ-TRO, Bert Parolari at (757) 518-2166. Coordination with the Virginia Beach Wetlands Board may be accomplished by contacting the Environment and Sustainability Office at (757) 385-4621 and/or VMRC, Justin Worrell at (757) 247-8063

2. Subaqueous Lands. In accordance with §28.2-1203 of the Code of Virginia, a permit must be obtained from VMRC for proposed impacts to state-owned subaqueous lands. The submission of a JPA by the Corps will include a review by VMRC of potential conflicts with current shellfish-lease activities related to commercial shellfish production, including any limitations on existing shellfish aquaculture activities from the proposed introduction of scallops as a new marine species. For additional information and coordination, contact VMRC, Justin Worrell at (757) 247-8068.

3. Nonpoint Source Pollution.

3(a) Erosion and Sediment Control and Stormwater Management Plans. This project must comply with Virginia's *Erosion and Sediment Control Law* (Virginia Code § 62.1-44.15:61) and *Regulations* (9 VAC 25-840-30 *et seq.*) and *Stormwater Management Law* (Virginia Code § 62.1-44.15:31) and *Regulations* (9 VAC 25-870-210 *et seq.*) as administered by DEQ. Activities that disturb 10,000 square feet or more of land (2,500 square feet or more in CBPAs) would be regulated by *VESCL&R* and *VSWML&R*. Erosion and sediment control, and stormwater management requirements should be coordinated with the DEQ Tidewater Regional Office, Noah Hill at (757) 518-2024.

3(b) Virginia Stormwater Management Program General Permit for Stormwater Discharges from Construction Activities. For projects involving land-disturbing activities of equal to or greater than one acre (2,500 square feet or more in CBPAs) and not covered under a VWPP or Corps permit, the applicant is required to apply for registration coverage under the Virginia Stormwater Management Program General Permit for Discharges of Stormwater from Construction Activities (9 VAC 25-880-1 *et* *seq.*). Specific questions regarding the Stormwater Management Program requirements should be directed to DEQ, Holly Sepety at (804) 698-4039.

4. Chesapeake Bay Preservation Areas. This project must be consistent with the Chesapeake Bay Preservation Act (Virginia Code §§ 62.1-44.15:67 *et seq.*) and *Chesapeake Bay Preservation Area Designation and Management Regulations* (Virginia Code 9 VAC 25-830-10 *et seq.*) as administered by DEQ. The project must be consistent with the conditions found in 9 VAC 25-830-140 for development in RPAs. For additional information and coordination, contact DEQ, Shawn Smith at (804) 527-5037.

5. Air Quality. Guidance on minimizing the emission of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) may be obtained from DEQ-TRO. Activities associated with this project are subject to air regulations administered by DEQ. The state air pollution regulations that may apply to the project are:

- fugitive dust and emissions control (9 VAC 5-50-60 *et seq.*); and
- open burning restrictions (9 VAC 5-130 *et seq.*).

Contact the City of Virginia Beach fire officials for any local requirements on open burning. For additional information, contact DEQ-TRO, Troy Breathwaite at (757) 518-2006.

6. Waste Management. All solid waste, hazardous waste, and hazardous materials must be managed in accordance with all applicable federal, state, and local environmental regulations. Some of the applicable state laws and regulations are:

- Virginia Waste Management Act (Code of Virginia Section 10.1-1400 *et seq.*);
- *Virginia Hazardous Waste Management Regulations* (*VHWMR*) (9 VAC 20-60);
- *Virginia Solid Waste Management Regulations* (*VSWMR*) (9 VAC 20-81); and
- *Virginia Regulations for the Transportation of Hazardous Materials* (9 VAC 20-110).

Some of the applicable federal laws and regulations are:

- Resource Conservation and Recovery Act (RCRA) (42 U.S.C. Section 6901 *et seq.*);
- Title 40 of the Code of Federal Regulations; and
- U.S. Department of Transportation Rules for Transportation of Hazardous materials (49 CFR Part 107).

Contact DEQ-TRO, Milt Johnston at (757) 518-2151 for information on the location and availability of suitable waste management facilities in the project area if contaminated sediments are encountered.

7. Natural Heritage Resources.

(i) Princess Anne, Great Neck North, Mill Dam Creek, and Great Neck South Wetland Restoration/Diversification Sites

For additional information and coordination on strategies for the control of *Phragmites*, contact DCR-DNH, Stewardship Biologist, Kevin Heffernan at (kevin.heffernan@dcr.virginia.gov or (804) 786-9112.

(ii) Natural Heritage Resources

Contact DCR-DNH, Rene Hypes at (804) 371-2708, to secure updated information on natural heritage resources if a significant amount of time passes before the project is implemented, since new and updated information is continually added to the Biotics Data System.

8. Wildlife Resources. Contact the USFWS Virginia Field Office at (804) 693-6694 and DGIF, Amy Ewing at (804) 367-2211 to discuss the site specific information necessary to determine potential project impacts on listed species.

9. Historic and Archaeological Resources. The Corps must coordinate this project with the Department of Historic Resources pursuant to Section 106 of the National Historic Preservation Act (as amended) and its implementing regulations at 36 CRF Part 800. For additional information and coordination, contact DHR, Roger Kirchen at (804) 482-6091.

Thank you for the opportunity to review the Environmental Assessment for the proposed Lynnhaven River Basin Ecosystem Restoration Project in the City of Virginia Beach. Detailed comments of reviewing agencies are attached for your review. Please contact me at (804) 698-4325 or John Fisher at (804) 698-4339 for clarification of these comments.

Sincerely,

Ellie L. Irons, Program Manager
Environmental Impact Review

Enclosures

Ec: Cindy Keltner, DEQ-TRO
Steve Coe, DEQ-DLPR
Kotur Narasimhan, DEQ-Air
Larry Gavan, DEQ-Water
Holly Sepety, DEQ-Water

Lynnhaven River Basin Ecosystem Restoration
U.S. Army Corps of Engineers

Daniel Moore, DEQ-Water
Tony Watkinson, VMRC
Robbie Rhur, DCR
Amy Ewing, DGIF
Barry Matthews, VDH
B. Keith Skiles, VDH-DSS
Roger Kirchen, DHR
Clay Bernick, City of Virginia Beach
Dwight Farmer, Hampton Roads PDC

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Planning and Policy Division

MAR 0 6 2014

Ms. Ellie Irons
Program Manager, Environmental Impact Review
Department of Environmental Quality
P.O. Box 1105
Richmond, Virginia 23218

Dear Ms. Irons:

This is in response to your letter dated November 13, 2013, providing comments on the Final Feasibility Report and Integrated Environmental Assessment for the Lynnhaven River Basin Ecosystem Restoration, City of Virginia Beach, Virginia. Your comments pertain to concerns with coordination with Virginia's regulatory and resource agencies and compliance with applicable state regulations and requirements. Your letter provided a helpful summary of our prior coordination and commitments with your agency.

Detailed responses to each of your comments related to the project are provided in the Enclosure. The USACE has been working with many of the commenting state agencies through the Lynnhaven River Basin Ecosystem Restoration Project Steering Committee during the planning of this project and looks forward to continued coordination. Many of the concerns included in your comments have been discussed at Steering Committee meetings and incorporated into our analysis. We are committed to continuing to work with your office and the various state agencies as this project moves through its design and construction phases to ensure that all stakeholder and trust resource concerns are adequately addressed.

We look forward to continuing our work together to bring this project to a successful and environmentally responsible completion. If you have further questions or concerns please contact Deborah Scerno at Deborah.h.scerno@usace.army.mil or (202) 761-5451.

Sincerely,

Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

Enclosure

ENCLOSURE

Responses to Commonwealth of Virginia Comments during State and Agency Review of the Final Feasibility Report and Integrated Environmental Assessment For the Lynnhaven River Basin Ecosystem Restoration, City of Virginia Beach, Virginia (November 2013)

General:

The USACE has committed in the Final Feasibility Report and Integrated Environmental Assessment to obtain all necessary permits for the project. This would include submittal of a Joint Permit Application (JPA) to the VMRC, DEQ, USACE and local wetland boards. The USACE understands that the JPA will include a review by VMRC of potential conflicts with current shellfish lease activities related to commercial shellfish production. Please note that some comments from DEQ were "Recommendations" which are recommended but not required and others are "Requirements" which are required per law or regulation. The page number, agency, and distinction between recommendation and requirement are noted prior to each comment. Agency comments are underlined.

Responses to Specific Comments:

Page 2, DEQ reference VMRC, general comment: As discussed in VMRC's May 24, 2013 letter to the Norfolk District of the USACE (attached), proposed project activities may conflict with current shellfish lease activities (i.e. coastal uses) in the Lynnhaven basin, as most of the lower Lynnhaven is currently leased for commercial shellfish production. In addition, the proposed establishment of submerged aquatic vegetation and scallops in identified areas may limit existing shellfish aquaculture activities as well as public access to areas within the Lynnhaven watershed. Accordingly, during the Joint Permit Application (JPA) review process, proposed project impacts to existing leases will require a notification to the leaseholder(s) of record and confirmation that they agree with the proposed activity on their leases. The benefits and detriments of the proposed activities will be weighed by VMRC before a permit decision is reached.

Response: The non-federal sponsor, the City of Virginia Beach, will acquire river bottomlands that are not currently leased to third parties. If the City is unable to acquire enough acreage through unleased sites, then leased areas will be acquired through negotiation or purchase of the leases. In addition, the City of Virginia Beach has committed to applying for a permit from VMRC to allow the construction of the Project components on the bottomlands and requesting a special designation by the VMRC that will designate the Project components as areas of protection in perpetuity.

The USACE will continue to coordinate with VMRC and DEQ to determine the appropriate time to submit the JPA. This will likely occur once the City of Virginia Beach has obtained the necessary leases. The City of Virginia Beach will continue to work to obtain the real estate needed for the project. This may include directly leasing areas that are not currently leased as well as negotiating with current leaseholders to obtain their leases. The SAV and scallop activities would be in areas set-aside for restoration purposes and therefore should not be in conflict with either the existing shellfish activities or public access. In addition, USACE will consider alternative protection measures such as no wake zones. These proposed activities will continue to be coordinated with your agency.

Page 4, VMRC, 1(c) Recommendation: The project must comply with section 404 (b)(1) guidelines of the Clean Water Act and with the Commonwealth's wetlands mitigation policies. Both federal and state guidelines recommend avoidance and minimization of wetlands impacts as the first steps in the mitigation process. To minimize unavoidable impacts to wetlands and waterways, DEQ recommends the following practices (responses provided below each bullet):

- Operate machinery and construction vehicles outside of stream-beds and wetlands; use synthetic mats when in-stream work is unavoidable.
  Response: Concur as practicable. The contractor will minimize disturbance which could cause mud waves, etc., which may impact the hydrology of the area. Contractor will use mats as appropriate.

- Preserve the top 12 inches of trench material removed from wetlands for use as wetland seed and root-stock in the excavated area.
  Response: Typically this would be a good seed source, however, the areas being excavated for this project are heavily infested with *Phragmites*. Therefore, the wetland areas will be seeded with a natural seed mixture and the top 12 inches of material will be disposed of in a manner that will reduce the spread of *Phragmites*.

- Design erosion and sedimentation controls in accordance with the most current edition of the Virginia Erosion and Sediment Control Handbook. These controls should be in place prior to clearing and grading, and maintained in good working order to minimize impacts to State waters. The controls should remain in place until the area is stabilized.
  Response: Concur. It will be a contract requirement for these controls to be in place throughout the length of the project.

- Place heavy equipment, located in temporarily impacted wetland areas, on mats, geotextile fabric, or use other suitable measures to minimize soil disturbance, to the maximum extent practicable.
  Response: Mats will be used to the maximum extent practicable, as described above and as appropriate at each site, to minimize impacts to adjacent wetlands and minimize soil disturbance.

- Restore all temporarily disturbed wetland areas to pre-construction conditions and plant or seed with appropriate wetlands vegetation in accordance with the cover type (emergent, scrub-shrub, or forested). The applicant should take all appropriate measures to promote revegetation of these areas. Stabilization and restoration efforts should occur immediately

after the temporary disturbance of each wetland area instead of waiting until the entire project has been completed.
Response: Concur. The sites will be revegetated as appropriate per site. Areas impacted through egress and access of the site will be restored to pre-project conditions or, if part of the project, as specified in the project.

- Place all materials which are temporarily stockpiled in wetlands, designated for use for the immediate stabilization of wetlands, on mats, geotextile fabric in order to prevent entry in State waters. These materials should be managed in a manner that prevents leachates from entering state waters and must be entirely removed within thirty days following completion of that construction activity. The disturbed areas should be returned to their original contours, stabilized within thirty days following removal of the stockpile, and restored to the original vegetated state.
Response: No stockpile areas will be in or immediately adjacent to wetlands. Locations where the contractor does stockpile, will be protected with erosion control measures. Stockpile areas will also be restored to their original vegetative states.

- Flag or clearly mark all non-impacted surface waters within the project or right-of-way limits that are within 50 feet of any clearing, grading, or filling activities for the life of the construction activity within that area. The project proponent should notify all contractors that these marked areas are surface waters where no activities are to occur.
Response: It will be a contract requirement to clearly mark all surface waters, including jurisdictional wetlands, on the plans and be flagged during construction.

- Employ measures to prevent spills of fuels or lubricants into state waters.
Response: Concur, the contractor will be required to develop and follow a spill prevention plan as part of their contract.

The Corps should work closely with the Wetlands Board staff to ensure that the proposal qualifies for a local exemption.
Response: Concur. USACE will work with the local wetlands board to ensure that the project qualifies for an exemption.

Page 5, VMRC, 1(d) Requirement: The initiation of the VWPP review process is accomplished through the submission of a Joint Permit Application (JPA) (form MRC 30-300) to the VMRC. Upon receipt of a JPA for the proposed surface waters impacts, VWPP staff at DEQ-TRO will review the proposed project in accordance with the VWPP regulations and guidance. In addition, any potential jurisdictional impacts to tidal wetlands will be reviewed by VMRC during the JPA review process.

Response: USACE understands this requirement and will be submitting the JPA as discussed above.

Page 6, VMRC, 2(c) Requirement: As mentioned above, the JPA review process includes an agency review to identify potential benefits and detriments to the marine resource and public uses. In addition, a public interest review is undertaken including requests for comments and questions. VMRC believes it is likely the project elements could change based on the public interest review required for any permits needed for encroachments over state-owned submerged lands.

Response: As stated above, the USACE will submit the JPA and work through that process with VMRC and DEQ. The City of Virginia Beach will continue to work to obtain the real estate needed for the project. This Project has included many opportunities for public input, following USACE standard protocols, and information was provided on approximately where the restoration activities would occur. Opportunities for public input included early scoping meetings, public meetings to discuss proposed alternatives, an executive steering committee which included various agencies and organizations (including VMRC), as well as the public review of the draft document and environmental assessment in the spring of 2013. The draft document was clear that bottoms, some currently leased for oyster harvest, would be sought for this project. We are confident that further public review will not raise any new issues.

Page 6, DEQ, Requirements:

(i) Erosion and Sediment Control and Stormwater Management Plans:According to DEQ, the Corps and its authorized agents conducting regulated land- disturbing activities on private and public lands in the state must comply with the *Virginia Erosion and Sediment Control Law and Regulations* (VESCL&R) and *Virginia Stormwater Management Law and Regulations* (VSWML&R), including coverage under the general permit for stormwater discharge from construction activities, and other applicable federal nonpoint source pollution mandates (e.g. Clean Water Act-Section 313, federal consistency under the Coastal Zone Management Act). Clearing and grading activities, installation of staging areas, parking lots, roads, buildings, utilities, borrow areas, soil stockpiles, and related land-disturbing activities that result in the total land disturbance of equal to or greater than 10,000 square feet (2,500 square feet in Chesapeake Bay Preservation Areas) would be regulated by VESCL&R. Accordingly, the applicant must prepare and implement an erosion and sediment control (ESC) plan to ensure compliance with state law and regulations. The ESC plan is submitted to the DEQ Tidewater Regional Office that serves the area where the project is located for review for compliance. The applicant is ultimately responsible for achieving project compliance through oversight of on-site contractors, regular field inspection, prompt action against non-compliant sites, and other mechanisms consistent with agency policy. [Reference: VESCL 62.1-44.15 et seq.]

(ii) Virginia Stormwater Management Program General Permit for Stormwater Discharges from Construction Activities:

The portions of the project requiring VWPP permitting from DEQ or Section 404 Clean Water Act permitting from the Corps are not required to obtain VSMP permitting for stormwater discharges from construction activities. For any portions of the project not covered under the aforementioned permits, the operator or owner of a construction project involving land-disturbing activities equal to or greater than one acre (2,500 square feet or more in areas analogous to CBPA) is required to register for coverage under the General Permit for Discharges of Stormwater from Construction Activities and develop a project specific stormwater pollution prevention plan (SWPPP). The SWPPP must be prepared prior to submission of the registration statement for coverage under the general permit and the SWPPP must address water quality and quantity in accordance with the VSMP Permit Regulations. General information and registration forms for the General Permit are available on DEQ's website at http://www.deg.virginia.gov/Programs/Water/StormwaterManagemenWSMPPermits/ConstructionGeneraiPermit.aspx. [Reference: Virginia Stormwater Management Act 62.1-44.15 et seq.] VSMP Permit Regulations 9 VAC 25-870-10 et seq.].

Response: An erosion and sediment control plan will be developed for the wetland restoration construction sites included in this project. Once a contractor has been chosen to construct the project, their contract with the USACE requires them to comply with all environmental laws, obtain necessary permits and submit required conservation plans (including the erosion and sediment control plan). This is standard in contracts for USACE construction projects. USACE ensures that the contractor obtains the appropriate permits. This will be a government-approved submittal and reviewed by the technical team. It is generally accepted practice for the government to require the contractor to provide the Stormwater Pollution Prevention Plan (SWPPP), which is then reviewed by the government. All requirements of these regulations, as discussed above, will be executed by the contractor with USACE oversight.

***DEQ, Page 7, General Comment*:** Most of the proposed projects will occur solely upon the subaqueous bottomland of the Lynnhaven River or its tributaries, and are therefore located outside of the jurisdiction of the Chesapeake Bay Preservation Act. There are, however, four wetland restoration projects which will occur within Resource Protection Areas (RPAs). Wetland restoration projects are considered water dependent activities under Section 9 VAC 25-830-140.1 of the Regulations and are permitted provided a water quality impact assessment is submitted to DEQ in accordance with Section 9 VAC 25-830-140.6.

Response: In compliance with the Chesapeake Bay Preservation Act for work within the Resource Protection Area (RPA), the USACE will submit a water quality impact assessment to the City of Virginia Beach prior to construction. This is prepared by the USACE contractor and reviewed by the USACE technical team.

***Page 8, DEQ, 5 (c) Recommendation*:** The Corps should take all reasonable precautions to limit emissions of VOCs and NOx, principally by controlling or limiting the burning of fossil fuels.

Response: The USACE will take all reasonable precautions to limit emissions. Air quality impacts and measures to eliminate or control these impacts are discussed on pages 219-221 of the final report. As indicated in the report, there are no long term effects on air quality. However, short term effects may occur during construction activities, but are below the de minimis level that would require a determination of conformity with state/local plans. Construction activities will be limited to 40 hours a week for the six months expected for the wetland restoration, for which the most fossil fuel burning equipment will be utilized.

Standard control measures such as water trucks to keep the dust down, minimization of idling on the construction site, and other minimization measures will be implemented.

***Page 8, DEQ, Requirements*:** Fugitive dust must be kept to a minimum by using control methods outlined in 9 VAG 5-

50-60 et seq. of the Regulations for the Control and Abatement of Air Pollution. These precautions include, but are not limited to, the following:

- Use, where possible, of water or chemicals for dust control;
- Installation and use of hoods, fans, and fabric filters to enclose and vent the handling of dusty materials;
- Covering of open equipment for conveying materials; and
- Prompt removal of spilled or tracked dirt or other materials from paved streets and removal of dried sediments resulting from soil erosion.

Response: Standard control measures such as water trucks to keep the dust down, minimization of idling on the construction site, and other minimization measures will be implemented.

If project activities include the open burning or use of special incineration devices for the disposal of debris, this activity must meet the requirements of 9 VAG 5-130-10 through 9 VAG 5-130-60 and 9 VAG 5-130-100 of the Regulations for open burning, and it may require a permit. The Regulations provide for, but do not require, the local adoption of a model ordinance concerning open burning. The Corps should contact City of Virginia Beach officials to determine what local requirements, if any, exist.

Response: No open burning is anticipated. If any burning were to be necessary, USACE would coordinate directly with the City of Virginia Beach to determine local requirements for this activity.

Page 9, DEQ, 6 (c)(i) Recommendations: An environmental investigation at and near the sites selected should be conducted to identify any solid or hazardous waste sites or issues related to the project area. The databases include the Permitted Solid Waste Management Facilities, Virginia Environmental Geographic Information Systems (Solid Waste, Voluntary Remediation Program, and Petroleum Release sites), Comprehensive Environmental Response, Compensation and Liability Act Facilities, and Hazardous Waste Facilities databases. Access to these data bases is discussed in DLPR's detailed comments attached to this response.

Response: The measures proposed for the Lynnhaven Basin Restoration Project are not expected to result in the identification and /or disturbance of HTRW. The Phase I investigation of potential HTRW, in accordance with ER 1165-2-132 (USACE, 1992), included a couple of the databases mentioned above and is located in the Environmental Appendix of the final report. The other databases mentioned by DEQ were recently reviewed. The data gathered during the Phase I investigation and the review of the databases, indicated that there is no evidence that HTRW will be found within the wetland sites, when sediment is disturbed during construction.

Even though no HTRW is expected to be encountered, best management practices will be employed during construction at the construction sites to avoid the suspension of sediment and the release of any contamination into the water column. An erosion control plan will be developed and implemented to control the entry of sediments into the tidal streams and their migration downstream of the work area. Turbidity curtains will be required per specifications.

Page 10, DEQ, 6(c)(i) Recommendations: DEQ encourages all projects and facilities to implement pollution prevention principles, including the reduction, reuse, and recycling of all solid wastes generated. All hazardous wastes should be minimized, and managed properly.

Response: Concur. USACE contract specifications will maximize opportunities for pollution prevention. All opportunities to reduce, reuse, and recycle will be incorporated into the plans and specifications.

Page 10, DEQ, 6(d) Requirements: Material that is suspected of contamination or wastes that are generated must be tested and disposed of in accordance with applicable federal, state, and local laws and regulations. All waste material must be characterized in accordance with the Virginia Hazardous Waste Management Regulations prior to disposal at an appropriate facility. It is the generator's responsibility to determine if a solid waste meets the criteria of a hazardous waste which must be appropriately managed.

Response: Concur. It will be included in the specifications that if the contractor comes across any suspected contaminated material, they are to cease all operations and notify the contracting officer immediately. USACE would then take appropriate action depending on the type of material identified and applicable federal, state, and local laws and regulations. Waste that is not contaminated will be disposed of properly, first looking for opportunities to reduce, reuse and recycle, and as a last resort hauling to an appropriate disposal location.

Page 11, Department of Conservation and Recreation, General Comment: DCR supports the efforts to control *Phragmites australis* in the wetland restoration areas. However, DCR has the following concerns with the approach for *Phragmites australis* eradication within the Princess Anne and Great Neck North sites:

1. Excavation of the upper peat layer "in order to remove as much *Phragmites* australis as possible to prevent re-colonization" will likely not remove all *Phragmites* rhizomes. *Phragmites* rhizome penetrates six feet or more into marsh substrate. Rhizomes are very hearty and abundant in a dense stand. Re-sprouting of any remaining rhizome will quickly overcome any new plantings.
2. Such soil disturbance is likely to encourage new *Phragmites* growth from seed or rhizome fragments.
3. Excavation adds the potential for fragments of rhizome to break off and migrate to other areas and establish new stands of *Phragmites*.
4. Removal of the peat will also remove any surviving native seed bank.

In addition, for the Mill Dam Creek and Great Neck South sites, the proposed creation of channels and pools will encourage *Phragmites* growth and the building of upland mounds from excavated material will expand the existing *Phragmites* footprint.

Response: Although the proposed USACE action is not standard *Phragmites* eradiation, the intent of the restoration is to provide open water areas for wading birds and a variation in elevation in the marshes. This method will create a diversified habitat to improve aquatic habitat quality. *Phragmites* at these sites will still exist in some areas, but the dense stands will be broken up with open tidal waters which do not support the growth of *Phragmites*. Our design is based such that constructed upland areas will be of a sufficient elevation to not support P*hragmites*. In addition, native vegetation will be planted to compete with the *Phragmites*. It is understood that *Phragmites* will continue to occur in these wetlands It is not the project goal to eradicate all *Phragmites*; however, it is the project goal to provide enough elevation variation and natural vegetation to restrict *Phragmites* infestation. In addition, there is an adaptive management and monitoring program, described in the final document, that will allow the project to make adjustments, if necessary.

Page 12, DCR, 7(c)(i) Recommendations: Princess Anne, Great Neck North, Mill Dam Creek, and Great Neck South Wetland Restoration/Diversification Sites: DCR recommends three consecutive years of herbicide treatment which is a proven method of controlling *Phragmites*. In addition, soil disturbance should be minimized as much as possible to ensure the native seed bank is available to re-colonize the area. Please see the Marsh Invader! brochure (attached) for more details on the control of *Phragmites*.

Response: Herbicide treatment will be considered for the Princess Anne site and Great Neck North site. It would not be appropriate for the Great Neck South and Mill Dam Creek sites which will be constructed to increase habitat diversity. These sites already have extensive populations of *Phragmites* which would be very difficult to eradicate. USACE believes the restoration approach described in the final report (and the response to the previous question) will provide biological benefits at these sites without totally eradicating the *Phragmites*. Some of the upland sites created will be of an elevation not supportive of *Phragmites* and native plantings will also be used to establish diverse populations of vegetation.

Page 12, DCR, Recommendations: Contact DCR-DNH to secure updated information on natural heritage resources if a significant amount of time passes before the project is implemented, since new and updated information is continually added to the Biotics Data System.

Response: USACE will contact DCR for updated information on natural heritage resources if a significant amount of time passes before the project is implemented.

Page 13, Department of Health, General Comment: VDH-DSS finds that the project includes reef construction and shellfish restoration efforts in waters currently closed to direct shellfish harvest. VDH-DSS would not oppose the project provided that the Corps understands this limitation and the site can be sufficiently marked and patrolled to prevent illegal harvest.

Response: The project is not intended to provide harvesting of shellfish. The fish reefs are designed such that neither the use of dredges or tongs would be possible on these reefs. In addition, they are meant to be sanctuary areas (preserves) and an oyster "seed source" for the rest of the basin. The USACE does not have the authority to patrol or enforce sanctuary areas. Since the VMRC has this authority, the USACE will be in discussions with them on what actions they can/will provide and any recommendations for signage/designation/etc USACE will implement appropriate signage to mark the area – if discussions with VMRC indicate that it will be more helpful than harmful (i.e. it will keep people away vs. indicate where to find shellfish.. There have not traditionally been enough scallops in the Lynnhaven for the public to be interested in harvesting. If this changes before water quality is deemed sufficient for harvesting then discussions will take place with VMRC on recommended actions.

Page 13, DGIF, 8(c) Recommendation: Comment: 8(c) Recommendations. DGIF previously recommended that the EA be updated with site-specific information to support the finding that the project is not likely to result in adverse impacts upon listed species. DGIF requested that its staff and the U.S. Fish and Wildlife Service (USFWS) be provided the opportunity to review the information. In addition, DGIF recommended that the EA be updated to reflect the delisting of bald eagles within Virginia and that Virginia no longer maintains a list of "species of concern" and, therefore, no longer designates species as such.

Response: Site-specific information is included in the report, however USACE will reach out to staff at DGIF and USFWS to ensure that site-specific information is shared and coordinated. The de-listing of the bald eagle within Virginia and the fact that Virginia no longer maintains a "species of concern" list will be included in the errata sheet that will go in the report that is transmitted for authorization. USACE has coordinated with staff members from DGIF and USFWS through the project executive steering committee throughout the planning of the project and will continue to do so as the project moves forward.

Page 14, DHR, 10(b) Requirement: DHR did not respond to DEQ's request for comments on the EA. However, in comments submitted in response to the FCD previously submitted by the Corps for the proposal, DHR noted that the Corps or its agents must consult directly with DHR on individual activities carried out under this initiative as stated in Section 11.11 of the Draft EA, and pursuant to Section 106 of the National Historic Preservation Act (as amended) and its implementing regulations codified at 36 CFR Part 800 which require federal agencies to consider the effects of their undertakings on historic properties.

Response: The USACE submitted its findings concerning effects to historic properties from this undertaking to VDHR on May 22, 2013 and will continue to consult directly with DHR on all activities carried out under this project, as appropriate. Since no response was received on the submittal to VDHR, according to 36 CFR 800 (no objection within 30 days of receipt of an adequately documented finding), the USACE's responsibilities under section 106 have been fulfilled. In addition, informal verbal coordination has identified no issues of concern.

Email, DGIF, General Comment: As stated in previous comments regarding this project, a number of state and federally-listed species have been documented from the project area. However, based on the project scope and location, we do not anticipate these activities to result in significant adverse impacts upon these species or resources. We recommend coordination with the USFWS and NOAA Fisheries Service regarding impacts upon federally listed species.

Response: USACE has coordinated with USFWS and NOAA throughout the entirety of the planning process, and a Planning Aid Report was provided in December 2010 (Appendix C of the final report). Subsequent coordination has continued to occur with USFWS and NMFS and will occur through design and construction.

Email, DGIF, Recommendation We recommend conducting any in-stream activities during low or no-flow conditions, using non-erodible cofferdams or turbidity curtains to isolate the construction area, blocking no more than 50% of the streamflow at any given time, stockpiling excavated material in a manner that prevents reentry into the stream, restoring original streambed and streambank contours, revegetating barren areas with native vegetation, and implementing strict erosion and sediment control measures.

Response: Although the proposed activities are not located in streams or streambeds, many of these suggestions, such as revegetation and strict erosion and sediment control measures, are applicable to the project and will be implemented.

Email, DGIF, Recommendation We recommend that all tree removal and ground clearing adhere to a time of year restriction protective of resident and migratory songbird nesting from March 15 through August 15 of any year.

Response: Tree removal and ground clearing will primarily occur in executing the wetland restoration activities. Tree removal is expected to be minimal and of smaller diameter trees. The exact timing of these activities has not been determined, however, it is likely that these activities would occur during the fall and winter (outside of the protective time of year restriction) to ensure the sites are ready for native wetland plantings to be planted/seeded in the spring. If the time of year restriction for tree clearing cannot be observed, other means of ensuring that resident and migratory songbird nesting is not disturbed, such as surveys and monitoring prior to and during the construction activities, will be accomplished. Appropriate avoidance measures will incorporated, if nesting is found. This approach has been effective in previous projects and will be used during implementation for the Lynnhaven project.

FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

MAIN REPORT

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION

VIRGINIA BEACH, VIRGINIA

U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510-1096

July 2013 modified February 2014

EXECUTIVE SUMMARY

The purpose of this study is to evaluate ecosystem restoration within the Lynnhaven River Basin and develop the most suitable plan of ecosystem restoration for the present and future conditions for a 50-year period of analysis. The Lynnhaven River Basin, a tributary to the Chesapeake Bay, is located within the City of Virginia Beach, Virginia. This report was authorized by a resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted May 6, 1998.

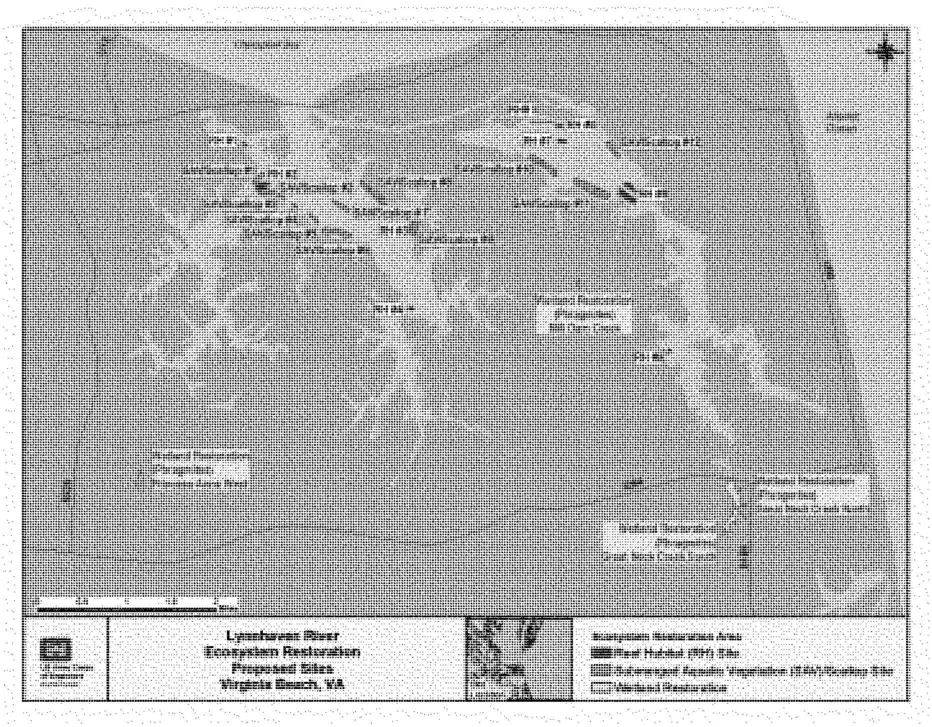
The study team, comprised of the non-Federal sponsor, the City of Virginia Beach, and representatives of Federal, State, and local governments, identified cost-effective and environmentally and technically sound alternatives to restore the ecosystem within the Lynnhaven River Basin. The process integrated the U.S. Army USACE of Engineer's (USACE) Campaign Plan in all aspects of the study process. In particular, the study meets Goal 2 of the Campaign Plan, which is to deliver enduring and essential water resource solutions through collaboration with partners and stakeholders. The study effort identified a "National Ecosystem Restoration" (NER) plan, which maximizes NER benefits in the most cost-effective manner through the restoration of ecosystem functions. The Recommended Plan of action is construction of the NER plan.

The principal project purpose is ecosystem restoration and includes restoration of wetlands and submerged aquatic vegetation (SAV), reintroduction of the bay scallop, and restoration of reef habitat.

The environmental decline of the Lynnhaven River has its roots in the agricultural methods used in the area over a century ago. Farming practices such as the clearing and tilling of fields resulted in increased amounts of sediment entering the water column, while inadequate waste management practices accounted for high levels of bacteria such as fecal coliform in the river. As the farms gave way to neighborhoods, the bacteria levels remained high due to the increased runoff from paved surfaces and leaking septic systems. The development of the Basin from a mostly agrarian region to a suburban area with shopping malls, industrial parks, and office buildings, much of which has occurred over the past 40 years, has adversely affected the biological life in and adjacent to the Lynnhaven River Basin in various ways. Concerns in the Lynnhaven River Basin include loss of SAV habitat, loss of reef habitat, reduced water quality, siltation, loss of tidal wetlands, increase in invasive wetland species and loss of Bay Scallops. Substantial local efforts are underway to address the problems identified above.

The Recommended NER Plan consists of restoration of approximately 38 acres of wetlands, 94 acres of SAV, reintroduction of the bay scallop on 22 acres of the SAV, and construction of 31 acres of reef habitat utilizing hard reef structures. This plan is identified among the other alternatives as "Plan D.4." No Locally Preferred Plan was suggested. The NER Plan is the Recommended Plan of improvement. The project plan is shown schematically in Figure i.

Figure i. LYNNHAVEN RIVER BASIN RECOMMENDED PLAN



The Recommended Plan was evaluated using a discount rate of 3.75 percent and fiscal year (FY) 2013 price levels. First costs of the project are currently estimated at $34,413,000. Expected annual costs are estimated at $1,529,000. The baseline cost estimate for construction in FY 2017 is $38,884,000. Details of first costs and annual costs at FY 2013 levels are shown in Table i.

Table i. ECONOMIC ANALYSIS, FY 2013 LEVELS, 3.75% INTEREST RATE

Item	October 2012 Price Level ($)
Construction	27,148,000
Adaptive Management[3]	1,750,000
Lands, Easements, and Rights of Way	725,000
Construction Management	2,127,000
Preconstruction, Engineering, and Design	2,663,000
Total First Costs	34,413,000
Interest During Construction	588,000
Total Investment Cost	35,001,000
Annual Costs[1]	
Interest and Amortization	1,497,000
Average Annual Monitoring[2]	30,000
Average Annual OMRR&R	2,000
Total Average Annual Costs	1,529,000

1. Annual costs are amortized over a 50-year period of analysis using the current discount rate of 3.75 percent.
2. Average annual monitoring costs include various amounts for each year of the 50-year period of analysis and for each project measure. It is expected that the initial 10 years of monitoring will be the most intense. All monitoring costs after the initial 10 years (including the fish reefs, wetlands, SAV, and scallops) will be the responsibility of the local sponsor, the City of Virginia Beach.
3. Adaptive management is a structured, iterative process designed to learn from the lessons of the past in order to adjust accordingly and improve the chance of project success. This discussion is located in Section 9.5.

Agency Technical Review (ATR) on this draft report was conducted in accordance with the USACE' Engineering Circular (EC) 1165-2-214. The report has been reviewed by USACE staff outside the originating office, with the review being conducted by a regional and national team of experts in the field, and coordinated by the National Planning Center of Expertise Ecosystem Restoration, Mississippi Valley Division, and USACE. Comments and responses will accompany the report. Documentation of ATR certification will accompany the report.

The Recommended NER Plan of improvement is considered to be environmentally acceptable. The analyses and design of the recommendations contained in this report comply with the National Environmental Policy Act (NEPA). A separate Environmental Assessment (EA) will not be provided, since the document is a fully-integrated report that complies with both NEPA requirements and the USACE (and Federal) water resources planning process and its requirements. The report complies with all applicable environmental statutes.

The report fully discusses areas of risk, uncertainty, and consequences, where that information is appropriate, such as failure of SAV to establish due to cow nose ray foraging, boat propeller damage, or storm events resulting in freshwater surges or an adverse change in water quality. These risks would also affect Bay Scallops which is dependent on SAV for habitat. All recommendations made in the report are capable of being adaptively managed, should that capability be needed. For instance, replanting may or may not be needed on some of the wetland restoration sites depending on the occurrence of large storms.

The Federal and non-Federal investments required to implement the current project proposal would equate to 65-percent for the Federal share and 35-percent for the non-Federal share. The Federal share of the project costs is currently estimated at $22,368,000. The non-Federal share of the project costs is currently estimated at $12,045,000. Fully funded at the baseline year of construction, FY 2017, the Federal share of the project costs is estimated at $25,275,000 and the non-Federal share of the project costs is estimated at $13,609,000. The Adaptive Management (AM) Plan for the project would be implemented, as needed, within the first ten years of the project. During this time, the AM would be cost shared with the non-Federal sponsor. After the first ten years, it would be the non-Federal sponsor's responsibility to maintain, rehabilitate, and repair the restored sites at full expense.

RECOMMENDATIONS

Wetland Restoration/Diversification. Four sites within the Lynnhaven River Basin have been identified for restoration or diversification of wetlands. Each site currently contains established stands of the non-native, invasive, emergent plant, *Phragmites australis*.

Two sites, the Princess Anne (3.82 acres) and the Great Neck North sites (19.98 acres), are selected for restoration of the indigenous salt marsh community and reduction of the population of invasive plant species, *Phragmites australis*, growing on site. Habitat restoration will involve both physical alteration of the site and herbicide application. Within areas that are dominated by *P. australis* and can be accessed by heavy construction equipment, the *P. australis* stands will first be treated with an herbicide approved for wetland use to kill existing foliage. The upper peat layer will be excavated in order to remove as much *P. australis* material as possible to prevent recolonization and to grade the site to the elevation optimal for the growth of *Spartina alterniflora,* a native salt marsh grass that inhabits the lower marsh. Features such as shallow pools, upland islands, and channels will be created to increase the diversity of the marsh habitat and to allow seawater to flood the area. Finally, the bare substrate will be planted with lower marsh plants, such as *S. alterniflora*, upper marsh plants, e.g. *Spartina patens*, and marsh bush species including *Iva frutescens* and *Baccharus halimfolia*.

Ecological function at two other sites, the Mill Dam Creek (0.9 acres) and Great Neck South (13.68 acres) sites, will be established by increasing habitat diversity. It was determined that the replacement of *P. australis* with the native marsh community would not be successful due to tidal restriction and reestablishing the full tidal range was prohibitively expensive. Instead, ecological function will be increased through the construction of habitat features, including islands, channels, and pools, in order to break up the homogeneous *P. australis* stands. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material. The material excavated from the tidal creeks and pools will be used to build upland mounds that will be planted with native shrubs or grasses.

Submerged Aquatic Vegetation. The twelve selected sites are in Broad Bay (42 acres) and the Lynnhaven Mainstem (52 acres). The sites will be planted with SAV seeds of two species, *Ruppia maritima,* widgeongrass, and *Zostera marina,* eelgrass. Widgeongrass has a broader range of environmental tolerances than eelgrass and should be able to quickly colonize the areas it is planted in. Seeds will be planted from small boats, likely Carolina skiffs, which are suitable for use in shallow water. Seeds may also be planted using divers or mechanical planters operated off a small boat (ERDC/TN SAV-080-1 March 2008). Due to the greater environmental tolerances of widgeongrass, early efforts will be more focused on restoring it, though restoration of eelgrass will be attempted simultaneously in sites where it has the greatest chance for establishment. Once the widgeongrass is established, it should provide for more stable bottom and better water quality conditions conducive to the survival of eelgrass, which should then proliferate over a wider area. It is expected that the SAV beds established in the Lynnhaven River will be a mix of widgeongrass and eelgrass, with widgeongrass dominating. Monitoring will be done to determine the full extent of the SAV beds. SAV adaptive management techniques will be evaluated and implemented accordingly.

Reintroduction of Bay Scallops. The 12 sites selected for reintroduction of the bay scallop are located within the SAV restoration sites and total approximately 22 acres. The SAV beds would be restored first, as Bay Scallops are known to prefer SAV to other substrates. No scallop restoration would commence until a minimum of one year after SAV restoration begins. If SAV is not successful after the first year, under the Adaptive Management (AM) Plan, alternate restoration techniques will be evaluated and implemented accordingly to improve the success of SAV before any Bay Scallops would be introduced. USACE expects scallops to also colonize other substrates, such as oyster reef habitat and macroalgae beds, particularly the red algae *Gracilaria vermiculophylla,* which have been shown to improve the survival of juvenile blue crabs, *Callinectes sapidus,* in a fashion similar to that of SAV beds (Falls, 2008).

Two main techniques are used in restoring Bay Scallops, direct stocking of juveniles or adults within SAV beds or use of broodstock adults, which are kept in cages at high densities to protect them from predators and aggregate them for increased spawning efficiency. A combination of both techniques, broodstock adults kept in cages as well as direct stocking of juveniles and adults, within restored SAV beds would increase the chances for successful re-introduction of the bay scallop to the Lynnhaven River. For broodstock, a minimum of 150,000 adults is recommended and an additional stocking of juveniles of at least 300,000 is recommended. The adult broodstock cages will be placed on the bottom at several locations. There are several types of cages and netting systems available for use. The preferred time of year for scallop restoration is from August through September.

Reef Habitat. The nine sites selected are located in the Lynnhaven Mainstem and the Broad Bay/Linkhorn complex. The sites in the Lynnhaven would restore approximately 10.5 total acres of low relief reefs by utilizing hard reef structures at density of approximately 2,000 hard reef structures per acre. The low relief hard reef structures are approximately two feet in height and three feet in width. The sites in the Broad Bay/Linkhorn complex would restore approximately 21 total acres of high relief reefs and consist of high relief hard reef structures at a density of 500 hard reef structures per acre. The hard reef structures range in size from four feet four inches in height and five and half feet in width to five feet in height and six feet wide (see Figures 6-8, Section 5.3.2).

The bottom conditions are relatively firm sandy bottom for most of the selected sites. One site in Broad Bay has some soft bottom that would require the placement of rock filled mats on the bottom prior to the placement of hard reef structures in order to prevent subsidence. This area is approximately ten acres in size.

Lynnhaven River Basin Ecosystem Restoration
FINAL FEASIBILITY REPORT
AND
INTEGRATED ENVIRONMENTAL ASSESSMENT

ERRATA SHEET
February 2014

The following corrections, clarifications, and augmentations are made to the final FS/EA:

1. Appendix B and Main Report.

Due to the approval process crossing fiscal years, all cost figures were updated with FY2014 costs.

Table i. ECONOMIC ANALYSIS, FY 2014 LEVELS, 3.50% INTEREST RATE

Item	October 2013 Price Levels ($)
Construction	27,743,000
Adaptive Management	1,750,000
Lands, Easements, and Rights of Way	740,000
Construction Management	2,167,000
Preconstruction, Engineering and Design	2,709,000
Total First Costs	35,110,000
Interest During Construction	588,000
Total Investment Cost	35,698,000
Annual Costs	
Interest and Amortization	1,521,938
Average Annual Monitoring	30,000
Average Annual OMRR&R	2,000
Total Average Annual Costs	1,553,938

2. Executive Summary, Page iv.

Updated costs to read: "The Federal and non-Federal investments required to implement the current project proposal would equate to 65-percent for the Federal share and 35-percent for the non-Federal share. The Federal share of the project costs is currently estimated at $22,821,500. The non-Federal share of the project costs is currently estimated at $12,288,500."

3. 2.5.2 State Species, Page 46-47

It is noted that the bald eagle is no longer state-listed. In addition, Virginia no longer maintains a list of "species of concern" and therefore, no longer designates species as such.

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION
VIRGINIA BEACH, VIRGINIA
FEASABILITY REPORT AND INTEGRATED
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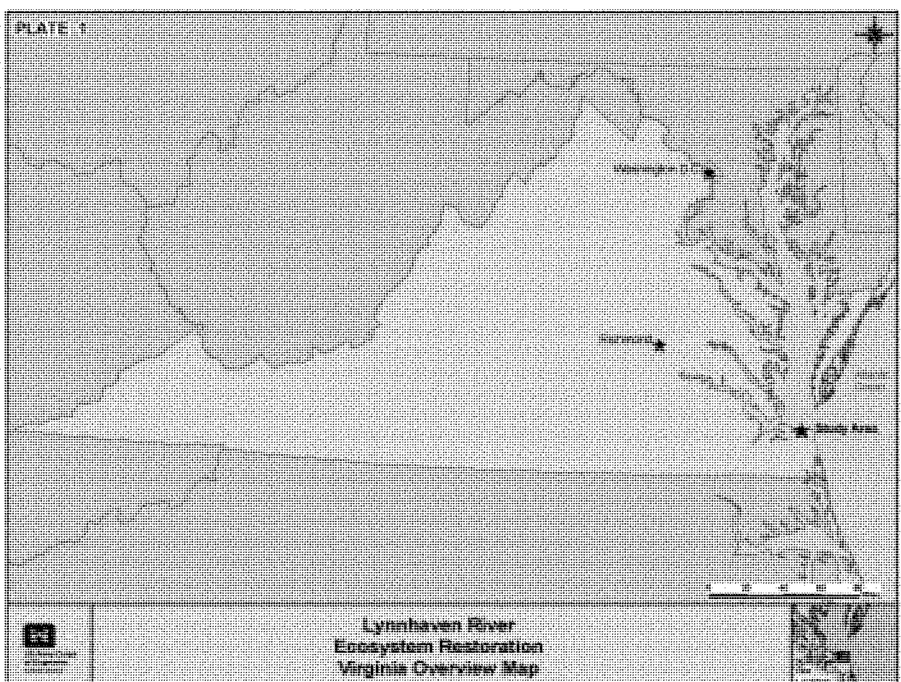
1.0 INTRODUCTION

The Lynnhaven River Basin Ecosystem Restoration Study focuses on the Lynnhaven River Basin, a Basin encompassing approximately 64 square miles and contained completely within the City of Virginia Beach (Figure 1). The Lynnhaven River is the largest tidal estuary in the city and lies in the heart of the urbanized northern half of the city. This resource has 150 miles of shoreline and hundreds of acres of marsh, mudflat, and shallow water habitats. The river attracts significant numbers of people, both local residents and tourists, due to the numerous recreational opportunities, including fishing, boating, crabbing, shell fishing, and bird watching, which are available within the system. However, the river has become increasingly impaired as the Basin has developed from a predominantly rural to a predominantly urban/suburban region. This conversion has subjected the river to environmental pressures that typically accompany land development and population increases.

Figure 1. PROJECT LOCATION



1.1 Study Authority

This study is authorized by Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted May 6, 1998. The authorization states:

> *Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, that the Secretary of the Army is requested to review the report of the Chief of Engineers on the Lynnhaven Inlet, Bay and connecting waters, Virginia, published as House Document 580, 80th Congress, 2nd Session, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of environmental restoration and protection and other related water resources purposes for the Lynnhaven River Basin, Virginia.*

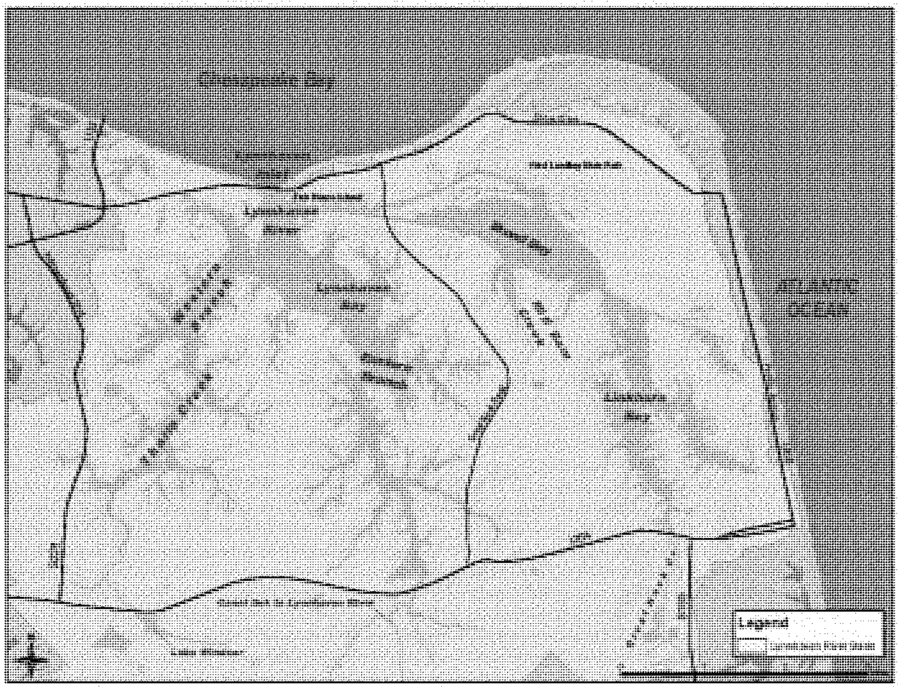
1.2 Study Purpose and Scope

The purpose of this integrated feasibility and environmental assessment is to provide a response to the study authority presented in the Congressional resolution. The study authority identifies issues to be addressed in the Feasibility Study, which are:

- Environmental Restoration and Protection; and
- Other water related resource purposes.

The report presents the assessment of alternative plans that meet the purposes of the study authority and determines whether the construction of alternatives for environmental restoration, protection, and related purposes for the Lynnhaven River, Virginia, is justified and in the Federal interest. This decision is based on an appraisal of the Federal interest and the consistency of potential solutions with current policies and budgetary priorities.

Figure 2. LYNNHAVEN RIVER BASIN



The scope of the study includes all existing and reasonably foreseeable future conditions that may affect the ecosystem within the Lynnhaven River Basin and its three main branches; the Eastern Branch, the Western Branch, and the Broad Bay/Linkhorn Bay complex. Figure 2 shows a map of the Lynnhaven River Basin and an outline of the watershed.

1.3 Significance of the Ecosystem

1.3.1 Institutional. The Lynnhaven River Basin is the southernmost tributary of the Chesapeake Bay. Recognition of the Chesapeake Bay as a living national treasure has long been a part of the regional and national conscience. More recently, the state and federal governments have heightened that recognition. The Chesapeake Bay was the first estuary in the United States targeted for intensive, government sponsored restoration efforts. Initiated and championed first by citizens, efforts were made to stop the pollution that had nearly killed the Bay by the early 1970s. In addition, Hurricane Agnes caused extensive SAV loss in the Chesapeake Bay including the Lynnhaven River (Orth and Moore 1983). The already weakened SAV beds were largely lost as a result of this catastrophic event. The Chesapeake Bay is now the focus of an intensive state/Federal restoration and protection effort.

In 1983 and 1987, the states of Virginia, Maryland, and Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and the U.S. Environmental Protection Agency (USEPA), representing the Federal government, signed historic agreements establishing the Chesapeake Bay Program partnership to protect and restore the Chesapeake Bay ecosystem (see Chesapeake Bay references in Appendix G). For almost three decades, these signatories have worked together as stewards to achieve better water quality and improvements in the productivity of living resources of the Bay. In the 1992 amendments to the Bay Program, the partners agreed to attack nutrients at their source: upstream in the Bay's tributaries.

In 1994, Federal officials from 25 agencies and departments signed the Agreement of Federal Agencies on Ecosystem Management in the Chesapeake Bay. This document outlined specific goals and commitments by Federal agencies on Federal lands, as well as new cooperative efforts by Federal agencies. These commitments were reaffirmed when the Bay Program partners came together on June 28, 2000 to sign the Chesapeake 2000 agreement. This comprehensive document set the course for the Bay's restoration and protection for the next decade and beyond. Congress, recognizing that the Chesapeake Bay is a national treasure and a resource of worldwide significance, enacted the Chesapeake Bay Restoration Act of 2000 reauthorizing the continuance of the Chesapeake Bay Program to implement the comprehensive cooperative restoration program.

In addition to the Chesapeake Bay Program, other laws have been implemented to aid in the restoration of the Bay and its tributaries. Section 704(b) of the Water

Resources Development Act (WRDA) of 1986, as amended through Section 505 of the WRDA of 1996; the re-authorization of Section 704(b); Section 342 of the WRDA of 2000; and the Section 704(b) as amended by Section 5021 of WRDA 2007 provided for the restoration of oysters within the Chesapeake Bay and its tributaries. The Lynnhaven River Basin is one of the tributaries where oyster restoration has been conducted in with an approved USACE document recommending 111 acres of oyster reefs. To date, approximately 63 acres of high and low relief oyster reefs have been constructed (58 by the USACE and five by others) which now accounts for almost the entire oyster and fish reef habitat within the Basin. These reefs are permanent sanctuaries and not to be fished for oysters. The high-relief reefs all exceed Federal metrics for oyster restoration success as defined by the NOAA-led Fisheries Goal Implementation Team of which the USACE is a member. Low-relief reefs do not perform as well as high-relief reefs, and many low-relief reefs are on a negative trajectory which will likely result in a return to an unrestored condition in the future.

Due to inadequate funding, the remaining acres called for in the oyster restoration plan for the Lynnhaven River have not been constructed to date, though it is hoped that they will be in the near future. The oyster restoration project within the Lynnhaven River Basin was the recipient of the 2009 Coastal America Award. The award recognizes outstanding efforts and excellence in leadership for protecting, preserving, and restoring the Nation's coastal resources and ecosystems.

In addition to Federal laws and actions, the Commonwealth of Virginia and the City of Virginia Beach have implemented their own requirements for restoring and protecting the Lynnhaven and the Chesapeake Bay. For instance, the Virginia Marine Resources Commission (VMRC) has instituted conservation measures designed to reduce the harvest of female blue crabs to address large declines in the fishery harvest. These measures included closure of the winter dredge fishery, a closure of spawning sanctuaries to harvest earlier, a required minimum size limit, and a requirement for larger escape rings in crab pots. Additionally, VMRC encourages shellfish gardening under piers or along shorelines and the use of living shorelines by allowing the construction to be done on some of the state owned bottom in the Lynnhaven and throughout the Chesapeake Bay.

In 1998, major portions of the Chesapeake Bay and its tidal tributaries within Virginia were identified as not meeting state water quality standards and were listed as impaired. The Lynnhaven River Basin was a part of this determination as elevated fecal coliform (FC) levels violated Virginia's FC water quality standard in shellfish supporting waters. The Virginia Department of Environmental Quality (VDEQ) completed a total maximum daily load (TMDL) study for Lynnhaven Bay, Broad Bay, and Linkhorn Bay that was approved by the USEPA in 2004. In 2006, the City of Virginia Beach developed a TMDL implementation plan.

Implementation of the plan resulted in some of the acreage in the Lynnhaven River Basin being opened to shellfish harvesting by lowering fecal coliform levels in several, but not all regions of the river. Because much of the Chesapeake Bay remained impaired in 2008, the six Chesapeake Bay Watershed States and the USEPA agreed that a Chesapeake Bay TMDL needed to be developed. The Chesapeake Bay TMDL will address all segments of the Bay and its tidal tributaries that are impaired. The USEPA established the Chesapeake Bay TMDL on December 29, 2010. The TMDL identified necessary pollution reductions for major sources of nitrogen, phosphorus, and sediment across the District of Columbia and large sections of Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia. The document sets pollution limits for the entire watershed necessary to achieve the Chesapeake Bay's water quality standards. This aggregate watershed loading will be divided among the Bay states and major tributary Basins, as well as by major source categories (wastewater, urban storm water, agriculture, and air deposition).

In addition, the City of Virginia Beach, The Trust for Public Land, and the Chesapeake Bay Foundation have partnered to purchase and protect 122 acres known as Pleasure House Point. Pleasure House Point is located within the Lynnhaven River Basin, west of the Lesner Bridge and Lynnhaven Inlet. It is one of the largest undeveloped tracts of land on the Lynnhaven River waterfront. The site had previously been proposed for a residential development known as Indigo Dunes and had faced fierce public opposition during the permitting process, but now it will remain as a protected area.

Recently, all of the laws and agreements affecting the restoration, protection, and conservation of the Chesapeake Bay have been brought into focus under the Chesapeake Bay Protection and Restoration Executive Order (EO) (EO 13508, http://executiveorder.chesapeakebay.net/), signed by President Barack Obama on May 12, 2009. The EO recognizes the Chesapeake Bay as a national treasure and calls on the Federal government to lead a renewed effort to restore and protect the Nation's largest estuary and its watershed. The EO tasked a team of Federal agencies to draft a way forward for the protection and restoration of the Chesapeake Bay watershed. As a guiding foundation for the strategy, Federal agencies drafted a vision statement that describes the desired conditions of the Chesapeake Bay and its watershed. This vision statement includes, among seven priority visions, "…a Chesapeake watershed with sustainable, healthy populations of blue crabs, oysters, fish, and other wildlife…" and, "…a broad network of land and water habitats that support life and are resilient to the impacts of development and climate change."

This team—the Federal Leadership Committee for the Chesapeake Bay—developed the *Strategy for Protecting and Restoring the Chesapeake Bay Watershed*, which was released in May 2010. That document sets out clear and aggressive goals, outcomes, and objectives to be accomplished through 2025 by the Federal government, working closely with state, local, and nongovernmental partners, to protect and restore the health of the Chesapeake Bay watershed. As directed in the EO, the Federal Leadership Committee will produce annual action plans to describe in finer resolution the actions to be taken in the coming fiscal year, based on the President's annual budget request to Congress. As a part of the Fiscal Year 2013 Action Plan, several activities have been identified that are vital to achieving the goals of the EO. These activities include:

- Restore Clean Water
- Recover Habitat
- Sustain Fish and Wildlife
- Conserve Land and Increase Public Access
- Expand Citizen Stewardship
- Develop Environmental Markets
- Respond to Climate Change
- Strengthen Science
- Implementation and Accountability

The Lynnhaven River Basin Feasibility Study directly supports the Recover Habitat and Sustain Fish and Wildlife objectives.

1.3.2 <u>Public.</u> The Lynnhaven River Basin is a treasured and pivotal part of the community in Virginia Beach. It is home to thousands of boaters and residents and it has become a daily part of life for many in the City of Virginia Beach. It is home to First Landing State Park, which is visited by thousands each year and contains beautiful cypress swamps and wetlands connected to the Lynnhaven River Basin. In the 1800's, the Lynnhaven River was the source of the world renowned oyster, the Lynnhaven Fancy. Only recently has harvesting oysters for consumption been allowed to resume in the watershed. Much of this is due to the efforts of the City of Virginia Beach, the Commonwealth of Virginia, Federal partners such as USACE and USEPA, and the work of nonprofit groups like Lynnhaven River NOW and the Chesapeake Bay Foundation.

In 2003, a committed group of local citizens came together to foster partnerships that would apply public and private resources to the challenge of restoring and protecting the Lynnhaven River Basin. That core group formed the nucleus of what has grown into an award winning river restoration organization with over 3,000 members called Lynnhaven River NOW. Lynnhaven River NOW was the recipient of the 2009 Governor's Environmental Excellence Award and was a recognized partner in the

Lynnhaven River Oyster Restoration Project when it received the 2009 Coastal America Award.

The primary goal of Lynnhaven River NOW is a clean and healthy Lynnhaven River. They have set out to identify and reduce sources of contamination in the river and reduce nutrients, sediments, and chemicals running off of lawns, parking lots, and roadways and out of septic systems. Through different initiatives Lynnhaven River NOW seeks to educate and engage the community and partner organizations in restoring and protecting the Lynnhaven River as well as to restore lost habitats such as oyster reefs, salt marshes, and other buffers that help to filter polluted runoff and protect the river and its marine life.

The Chesapeake Bay Foundation is another organization that is currently addressing the ecosystem restoration challenges posed by the Chesapeake Bay. Similar to the annual state of the bay report produced Lynnhaven River NOW, the Chesapeake Bay Foundation also issues a report card on the environment in the Chesapeake Bay, which grades the overall health of the Bay based on various factors. This organization also sponsors the annual "Clean the Bay Day" that is very popular in the Lynnhaven River Basin. The Chesapeake Bay Foundation has also partnered with Lynnhaven River NOW and the City of Virginia Beach to construct oyster reefs within the Lynnhaven River.

1.3.3 Technical. The Lynnhaven River has a heavily urbanized Basin that could serve as a microcosm of the Chesapeake Bay. The entire Lynnhaven drainage area makes up less than 0.01 percent of the Chesapeake Bay watershed. The transformation of undeveloped land, associated with the settlement and growth of the City of Virginia Beach, along with overfishing, climate change, and other factors, has fundamentally and negatively altered the ecology of the Lynnhaven River. Reduced water quality, declines in the amount of essential habitat types such as SAV, wetlands, and oyster reefs, and smaller populations of game fish, water fowl, reef dependent finfish, and other organisms are all results of the alteration of the system. The deterioration of the Chesapeake Bay is analogous to observed changes within the Lynnhaven River Basin.

Due to the efforts of the City of Virginia Beach and other organizations, improvements to water and habitat quality have been observed in the Lynnhaven system. However, the potential for significant environmental improvements still remains. Sea grass beds, which stabilize bottom sediments and provide important nursery habitat for a wide suite of marine life, have not recovered. Reef habitat, which was once very common, and wetlands, which were once extensive throughout the Chesapeake Bay watershed including the Lynnhaven, have been lost to development and are now almost entirely gone from the Bay and Lynnhaven River.

To shift the Lynnhaven River back to a prior, more productive and ecologically stable state will require a large scale effort such as is included within the proposed study. This scale of ecological output is necessary to effect a shift in baseline conditions, and along with abiotic controls, such as improvements in stormwater runoff and sewage treatment plant operations, will be needed to restore the Lynnhaven River (as well as the Chesapeake Bay) to a more productive, healthy, and stable ecological state than it is in currently. The Lynnhaven study and the projects described herein may serve as a microcosmic example of the level of effort that will be needed Bay-wide in order to return regional estuarine waters to a more pristine condition.

1.4 Study Sponsors, Participants, and Coordination

The USACE, Norfolk District Engineer is responsible for conducting the overall study in cooperation with the Executive Committee composed of representatives of the Norfolk District and the City Manager of the City of Virginia Beach. Coordination with field level representatives from the City of Virginia Beach, Hampton Roads Planning District Commission, Virginia Institute of Marine Science (VIMS), VMRC, Virginia Department of Conservation and Recreation (VDCR), VDEQ, the Virginia Department of Health(VDOH), Lynnhaven River Now Organization, The Chesapeake Bay Foundation, National Oceanic and Atmospheric Administration (NOAA), and U.S. Fish and Wildlife

Service (USFWS) has occurred throughout the study. This coordination ensures that the ecosystem restoration project, as proposed for the Lynnhaven River Basin, will be in harmony with ongoing Chesapeake Bay-wide efforts of Federal, state and local governments and that the implementation of the proposed project will produce the primary benefit of ecosystem protection and restoration.

1.5 Reconnaissance Phase Recommendations

A Reconnaissance Study was completed in January 2004, with the certification of the June 2002 report entitled "Section 905(b) (WRDA 86) Analysis, Lynnhaven River Environmental Restoration, Virginia Beach, Virginia". The objective of the Reconnaissance Study was to determination whether or not the planning process should proceed further, based on preliminary appraisal of the Federal interest and preliminary analysis of potential solutions for degraded habitat within the Lynnhaven River Basin. The report focused on six specific areas related to the degradation of natural resources in the Basin: water quality, tidal wetlands, oyster resources, SAV, siltation, and contaminated sediments.

The report concluded that there are environmentally sensitive solutions that can be formulated to result in substantial ecosystem restoration benefits. Further, the report specifically recommended that the USACE conduct a Feasibility Study with the City of Virginia Beach to address ecosystem restoration within the Lynnhaven River Basin.

1.6 Feasibility Study Purpose and Objectives

The Feasibility Report will present, through a plan formulation process, a National Ecosystem Restoration (NER) Plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objectives. The selected plan will be shown to be cost-effective and justified to achieve the desired level of output.

1.6.1 National Objective. The Federal objective of water and related land resources project planning is to contribute to national ecosystem restoration in a manner consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable EOs, and other Federal planning requirements. If the projected benefits of ecosystem restoration measures exceed their estimated costs and are judged acceptable, their construction as a Federal project would contribute to this objective and be in the Federal interest.

1.7 Studies and Reports

Prior USACE reports, studies, and existing water projects in the vicinity of the Lynnhaven River are listed below:

(1) Annual Report of Chief of Engineers for 1880; Senate Executive Document Number 104, 46th Congress, 2nd Session, March 3, 1879. This report evaluated the construction of a channel in Lynnhaven, Linkhorn, and Broad Bays, with a proposed connection between the Chesapeake Bay and the sounds of North Carolina. It was a favorable report; however, there was no action taken by Congress.

(2) Annual Report of Chief of Engineers for 1891; House Executive Document Number 48, 51st Congress, 2nd Session, September 19, 1890. This report evaluated establishing a waterway to connect Lynnhaven Bay with the Eastern Branch of the Elizabeth River. It was an unfavorable report.

(3) Annual Report of Chief of Engineers for 1892; House Executive Document Number 27, 52nd Congress, 1st Session, March 3, 1891. This report evaluated placing a breakwater in Lynnhaven Roads, the area located on the seaward side of the inlet to the Lynnhaven River, in order to form a harbor of refuge therein. It was a favorable report, however, there was no action taken by Congress.

(4) House Document Number 1244, 62nd Congress, 3rd Session, October 18, 1912. This report evaluated deepening portions of the Lynnhaven River. It was an unfavorable report.

(5) Not Published, December 10, 1928. A report was completed which evaluated construction of a channel from the mouth of Linkhorn Bay through the Narrows, Broad Bay, Long Creek, Lynnhaven River, and Lynnhaven Inlet. It was an unfavorable report.

(6) Not Published, November 16, 1933. This report evaluated the construction of jetties at Lynnhaven Inlet; a channel through Lynnhaven Inlet, Lynnhaven River, and the west end of Long Creek; a land cut between Long Creek and Broad Bay; drainage ditching of adjacent marshes; a sewerage disposal plant; and a culvert and flume to connect Linkhorn Bay with the Atlantic Ocean south of Virginia Beach. It was an unfavorable report.

(7) Not Published, March 5, 1938. This report evaluated construction of a channel in Lynnhaven Bay, Lynnhaven Inlet, and the Lynnhaven River. It was an unfavorable report.

(8) Lynnhaven Inlet, Bay and Connecting Waters, Virginia; House Document Number 580, 87th Congress, 2nd Session, September 25, 1962. This report evaluated constructing an entrance channel from Chesapeake Bay through Lynnhaven Inlet, 10 feet deep, 150 feet wide, and approximately 3,500 feet long; a mooring and turning Basin in Lynnhaven Bay, 10 feet deep, 1,100 feet long, and 750 feet wide; a channel 9 feet deep, 90 feet wide, and approximately 10,000 feet long from the mooring and turning Basin to Broad Bay via the Long Creek-Broad Bay Canal; and a channel through the Narrows, 6 feet deep, 90 feet wide, and approximately 2,000 feet long. Since approximately 52 percent of the benefits presented in the report were derived from increased shellfish production, the Board of Engineers recommended project benefits be re-examined before construction due to the introduction of the infectious organism known as Multinucleate Sphere X (MSX) into the Lower Chesapeake Bay. It was a favorable report and the project was constructed in phases as funding was provided by Congress.

(9) Virginia Beach, Virginia, Canal Number 2, 1973; The document was a favorable report and recommended construction of a canal from the Virginia Beach Boulevard Bridge to a point 880 feet south of Potters Road Bridge. It then proceeds in a southerly

direction, bypassing Princess Anne Plaza, until it intersects with the existing canal 700 feet north of the Ships Corner Road Bridge. From this point, it coincides with the existing canal to Ships Corner Road Bridge. It has a bottom width ranging from 25 feet to 80 feet and a depth of -8 feet m.s.l.

(10) Lynnhaven River, Decision Document Amendment, Chesapeake Bay Oyster Recovery Phase IV of Section 704(b) as amended, November, 2005; The document was a favorable report and recommended construction of 111 acres of oyster reefs within the Lynnhaven River Basin. Approximately 58 acres have been constructed to date.

(11) Identification and Assessment of Water Quality Problems in Mill Dam Creek and Dey Cove Tributaries of the Lynnhaven River, Virginia Beach, 2008; This study was conducted under Section 22 of the Water Resources Development Act of 1974 to identify and assess potential water quality problems in Mill Dam Creek, a small tributary entering the Broad Bay branch of the Lynnhaven River from the south (Sisson et al. 2009). Mill Dam Creek is a middle-sized tributary creek in the Lynnhaven River system, lying on the south shore of Broad Bay. Water quality problems are associated with this creek, and were studied using a hydrodynamic model as well as available water quality monitoring data. It was determined that salinity is susceptible to sharp decreases resulting from rainfall events, a 5 degree Celsius temperature increase from the confluence of Mill Dam Creek and Broad Bay to Upper Mill Dam Creek, and a strong diurnal Dissolved Oxygen (DO) oscillation, with intermittent hypoxic events that can last 2-3 days. The hypoxic events were associated with sharp decreases in salinity and chl-A concentrations (rain events). Fecal coliform modeling revealed a bacterial plume is associated in Mill Dam Creek with significant rainfall events. In conclusion, Mill Dam Creek is a hotspot of fecal coliform loading for Broad Bay, and prone to low water quality.

(12) A Numerical Modeling Assessment for the Implementation of a Runoff Reduction Strategy Plan for Restoration of Thalia Creek, Virginia, Planning Assistance to States Report (Sisson et al. 2010); identify and assess potential water quality problems in the Thurston Branch-Thalia Creek (TB-TC) system, a small tributary at the head of the

Western Branch of the Lynnhaven River. Thalia Creek is a small tributary creek at the head of the western branch of the Lynnhaven River. A high resolution hydrodynamic/water quality model was developed to assess the creek, in particular nutrient and fecal coliform levels, as well as DO and chl A. High levels of chl A were found, increasing with distance upstream from the confluence with the western branch, and indicated eutrophic conditions in the Creek. DO conditions varied, with hypoxic conditions noted and these conditions seem to be diurnal, influenced primarily by solar insulation as well as tidal action and freshwater input from significant rainfall events. Upper reaches of Thalia Creek typically exceed fecal coliform standards, while lower reaches fluctuate between shellfish and recreational water standards. Nonpoint source runoff is the primary driver of fecal coliform issues in Thalia Creek.

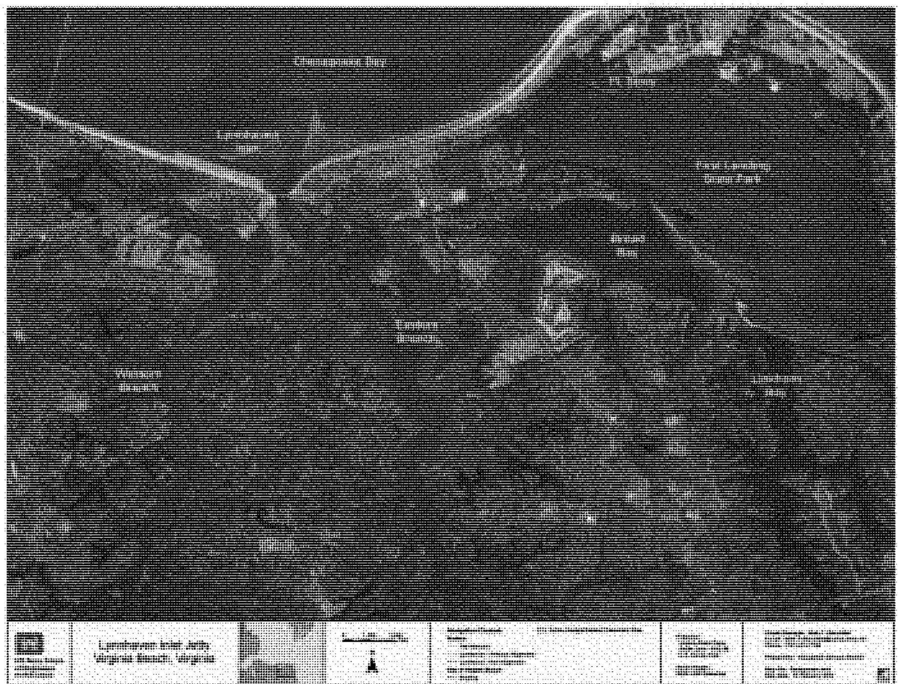
(13) Assessment of Oyster Reefs in the Lynnhaven River as a Chesapeake Bay Total Maximum Daily Load Best Management Practice; The purpose/scope of this project is to formally identify the ability of 2-dimensionally and 3-dimensionally constructed and naturally occurring oyster reefs to remove nitrogen, phosphorus, and sediment from the overlying water column, as a tool to meet the Chesapeake Bay TMDL requirements (Sisson et al. 2011).

1.8 Existing Water Projects

1.8.1 <u>Lynnhaven Inlet.</u> The authorized project has been constructed and provides for an entrance channel that is 10 feet deep and 150 feet wide extending 1 mile from that depth in the Chesapeake Bay to a mooring area and turning Basin that is 10 feet deep, 1,250 feet long, and 700 feet wide in Lynnhaven Bay, just upstream from the Lesner Bridge at the mouth of the inlet. The project can be seen below in Figure 3. A channel that is 9 feet deep and 90 feet wide extends eastward 2.0 miles from the mooring area and turning Basin to Broad Bay, via the Long Creek-Broad Bay Canal. There is also a channel that is 6 feet deep and 90 feet wide extending 0.5 mile through The Narrows connecting Broad and Linkhorn Bays. The project has a total length of approximately 5.2 miles. The project also includes a 0.3-mile side channel that is 8 feet deep and 100 feet wide, connecting into Long Creek.

Approximately 180,000 cubic yards of material are dredged from the channel every 3 years with a majority of material being deposited into a confined area just inside and on the west shore of the inlet. The last time the project was dredged was in 2010. Suitable sand from the channel has been used to nourish adjacent shoreline fronting the Chesapeake Bay and has also been transported by trucks to nourish the resort strip along the Virginia Beach oceanfront. The federal government, through the USACE, funds 100 percent of the cost to maintenance dredge this project. However, as local sponsor, the City of Virginia Beach is responsible for the provision of adequate placement areas and the cost of containment dikes and other site preparation. In addition, maintenance of local access channels and berthing areas are a local responsibility.

Figure 3. LYNNHAVEN INLET

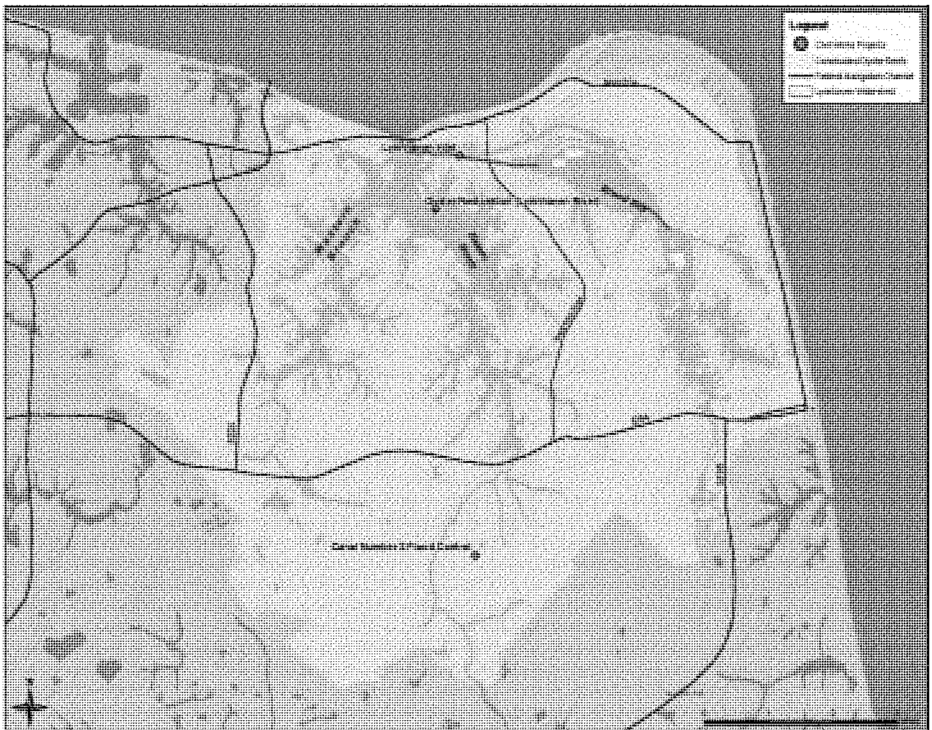


Lynnhaven Inlet is a very busy inlet that provides access for small commercial (blue crab harvesting, fishing and eco-tourism) and recreational vessel traffic to public and private docking facilities within Lynnhaven Inlet and connecting waters. There are also several seafood processing establishments and boat storage and repair facilities. In addition, numerous recreational vessels are moored along the connecting waters and use the inlet on a regular basis, particularly during the summer months. Two of the more prominent users are the Virginia Pilot Association and the Association of Maryland Pilots, both of whom have large pilot boats based inside the inlet.

1.8.2 Virginia Beach Canal No. 2. The authorized project has been constructed. Significant changes have occurred in the flood plain since the completion of the last report. Some reaches of the original report claimed damages for agriculture that has now been replaced by residences. There has been significant commercial and residential development in the area that is far above what was considered in the original report.

1.8.3 Lynnhaven Oyster Restoration. Approximately 58 acres of restored oyster reefs have been constructed to date out of the 111 acres recommended in the November 2005 decision document. The reefs were constructed out of shells dredged from buried shell deposits in the lower James River, cleaned, and transported to the Lynnhaven where they were placed at various locations in Linkhorn Bay, Broad Bay, the Eastern Branch, and Lynnhaven Bay as high-relief (≥ 1 foot) shell reefs. Subsequent monitoring has documented high recruitment to many of these reefs and currently large numbers of oysters, some as large as 8 inches in length, can be found on the restored reefs. These projects are shown below in Figure 4.

Figure 4. EXISTING WATER PROJECTS



2.0 EXISTING CONDITIONS

The project area is located entirely within the Lynnhaven River Basin, which is the southernmost tributary to the Chesapeake Bay in Virginia. The Lynnhaven River Basin, with its three branches, the Eastern, Western, and the Broad Bay/Linkhorn Bay, encompasses an area of land and water surface of nearly 64 square miles, which represents less than 0.4 percent of the area of Virginia and less than 0.01 percent of the Chesapeake Bay watershed. However, the Basin, representing one-fourth of the area of the City of Virginia Beach, performs vital functions to the city and its residents.

2.1 Study Area

The study area is located wholly within the boundaries of the City of Virginia Beach, Virginia. The City of Virginia Beach is located in Southeastern Virginia, approximately 100 miles from the state capitol in Richmond, Virginia. The Lynnhaven River Basin is a 64 square mile tidal estuary in the lower Chesapeake Bay Watershed.

2.2 Environmental Resources

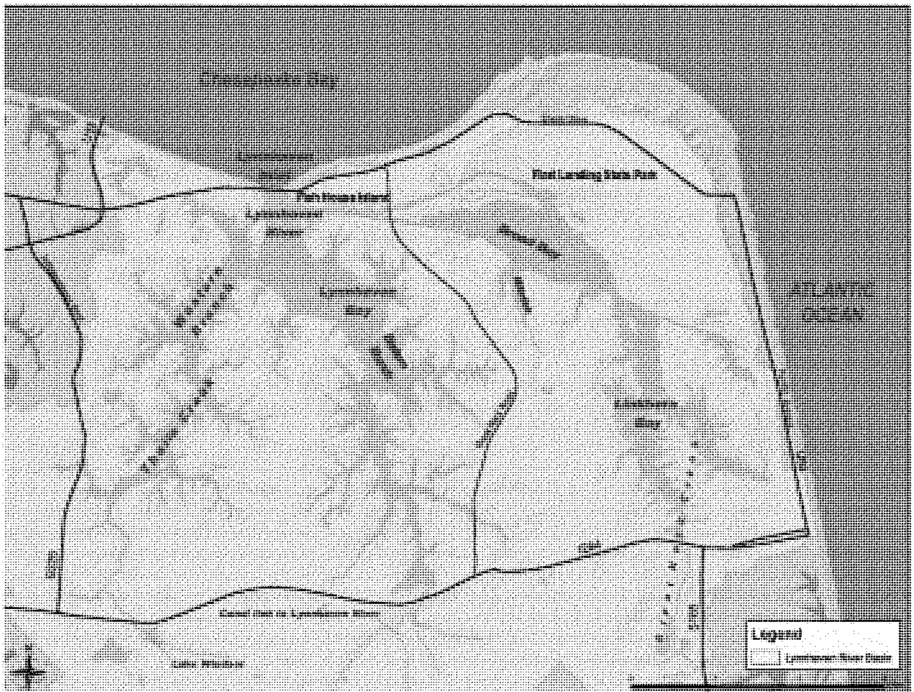
The following section of the report details the physical and biological resources of the Lynnhaven River Basin. The river comprises over 5,000 acres of surface waters (VDEQ, 1999). The Lynnhaven River's major tributaries are London Bridge Creek (Eastern Branch), Wolfsnare Creek (Eastern Branch), Great Neck Creek, Thalia Creek (Western Branch), Buchanan Creek (Western Branch), and Pleasure House Creek.

2.2.1 Climate. The climate of Virginia Beach, Virginia is temperate, humid subtropical, with long, warm summers and relatively short, mild winters. Average summer temperature is 77 degrees Fahrenheit (°F), with a maximum daily average of 85 °F. The average winter temperature is 42 °F, with an average daily minimum temperature of 33 °F. The total annual precipitation is 45 inches. During the fall and spring, nor'easters may impact the area, causing localized flooding (U.S. Department of Agriculture, 1985). Flooding in the Lynnhaven River basin can be caused by the combined effects of heavy precipitation and tidal events. These flooding events range from local nuisance flooding to more widespread events, such as flooding from hurricanes and major nor'easters.

2.2.2 Physiography, Relief, and Drainage. Virginia is made up of three physiographic areas: the Piedmont Plateau, the Blue Ridge and Allegheny Mountains of the Appalachian chain, and the Atlantic Coastal Plain, also known as the Tidewater area. The City of Virginia Beach falls into the Tidewater area. Virginia Beach has an average elevation of 12 feet above sea level. The Virginia coast is divided into four long peninsulas created by the Commonwealth's four principal rivers (the Potomac, Rappahannock, York, and James) and the Chesapeake Bay. Virginia Beach has an area of 497 square miles; 248 square miles consist of land and the other 249 are water. The Lynnhaven River Basin is a small tidal estuary (64 square miles) that empties into the Chesapeake Bay. The area is highly developed; however, there is a large amount of park land in the area. The largest park surrounding the Lynnhaven River, First Landing State Park, consists of salt marsh, coastal forest, open beach, and cypress swamp.

Virginia Beach is drained by four major river systems, namely the Lynnhaven, Elizabeth, and North Landing Rivers, as well as Little Creek. The Lynnhaven and Elizabeth Rivers and Little Creek all flow north, where they empty either into the James River or the Chesapeake Bay. The North Landing River drains the southern part of Virginia Beach, including drainage from West Neck Creek, and empties into Currituck Sound (Maguire Associates, 1993). Historically, numerous manmade canals were constructed in Virginia Beach primarily to provide drainage and flood control to the agricultural lands when the region was predominantly rural. One of the largest of these manmade waterways is Canal No. 2, which connects drainage from the headwaters of the Eastern Branch of the Lynnhaven River to West Neck Creek. As the land use around these canals has shifted from agricultural to residential and commercial, the original local drainage patterns in these areas continue to be modified. Figure 5 shows the major tributaries and drainage.

Figure 5. MAJOR TRIBUTARIES AND DRAINAGE OF THE LYNNHAVEN RIVER



2.2.3 Geology and Soils. In geologic terms, the Chesapeake Bay is very young. During the latter part of the Pleistocene epoch, which began one million years ago, the area encompassing the Chesapeake Bay was alternately exposed and submerged as massive glaciers advanced and retreated up and down North America. This movement caused sea levels to rise and fall in response to glacial expansion and contraction. The region still experiences changes in sea level, which have been observed over the past century.

The most recent retreat of the glaciers, which began approximately 10,000 years ago, marked the end of the Pleistocene epoch and resulted in the birth of the Chesapeake Bay. The melting glacial ice caused an increase in sea level that submerged the coastal regions, including the ancient Susquehanna River Valley along with many of the river's tributaries. The resulting complex of drowned stream beds now forms the Chesapeake Bay and its tidal tributaries, which includes the Lynnhaven River (USEPA, 1989).

Soils in the Lynnhaven River Basin are generally characterized as loams and sandy loams, which overlie deep deposits of unconsolidated stratified lenticular sand and silt, with some gravel and clay. The Virginia Beach area contains five major soil associations, as mapped by the Natural Resources Conservation Service of the U.S. Department of Agriculture (USDA). The Newhan-Duckston-Corolla association is found in the northern coastal areas along the Chesapeake Bay. This association is characterized by very permeable soils on nearly level to steep grass and shrub covered dunes, flats, and depressions with slopes ranging from 0 to 30 percent. The soils within this association range from excessively drained to poorly drained, with a sandy substratum. The State-Tetotum-Augusta association occurs in the northern part of the city, on nearly sloping to gently sloping areas on broad ridges and side slopes. The soils in this association are characterized as well-drained to somewhat poorly drained with loamy substrates. The Acredale-Tomotley-Nimmo association occurs mainly in the southern part of the city in broad, flat areas, with slopes ranging only from 0 to 2 percent. The soils of this association are characterized as poorly drained with a loamy substrate. The Dragston-Munden-Bojac association is found on narrow ridges and side slopes in various areas of the city. The soils in this association are characterized as nearly level, well to moderately well drained, with a loamy substrate. The last found within Virginia Beach is Udorthents-Urban. These soils are characterized as being formed through activities such as excavation and filling and are often covered by impervious surfaces, such as structures or roadways. They are nearly level to steep, well to moderately well drained soils with loamy substrates (USDA, 1985; Maguire Associates, 1993).

2.2.4 <u>Tides.</u> The astronomical tides affecting the project area are semi-diurnal, which means the tidal cycle consists of two high tides and two low tides each lunar day, where consecutive high tides are of similar height, and consecutive low tides are of similar height. The Lesner Bridge creates a constriction at the mouth of the Lynnhaven that influences the tidal flow throughout the system. Just north of the Lesner Bridge, the tidal range is approximately three feet (Maguire Associates, 1993). Tidal range in the Western Branch after a dredging cycle was reported as two feet (USACE, 1980). Combined tidal flow into the Lynnhaven complex was estimated to be 342,768,805 cubic feet (Chipman, 1948).

2.2.5 Submerged Aquatic Vegetation. SAV habitats contribute to numerous ecological functions, including sediment stabilization, nutrient transformation and cycling, primary production, and forage and nursery habitat for both recreationally and commercially important fish and shellfish. However, since the late 1960's and early 1970's, human activities worldwide and specifically within the Chesapeake Bay and its tributaries have threatened these habitats. Increased coastal development, leading to high nutrient and sediment inputs, has altered water quality, which is a critical component in supporting healthy seagrass populations (VDEQ, 2002b). This situation is evident in the waters of the Lynnhaven River.

SAV was once very abundant throughout the Chesapeake Bay, including the study area, but has experienced significant declines beginning in the 1930's. A large-scale die back occurred along the entire Atlantic coast and was believed to be due to a fungal disease. SAV did recover in the late 1930's to a level near its former abundance in many areas, including much of the Chesapeake Bay but not along the Eastern Shore of Virginia, which remains mostly denuded of SAV. Photographic evidence from the late 1930's (1938) shows that some SAV beds had recovered in the Lynnhaven River by that time.

Since the late 1960's, there has been a pollution induced, Bay-wide decline in SAV abundance and distribution in the Chesapeake Bay, including the study area. Additionally, in 1972, Tropical Storm Agnes reduced salinities significantly in the more typically saline portions of the Bay. It also transported huge quantities of sediments and nutrients into the Bay and its tributaries. The result was a massive die-off of SAV throughout the Chesapeake Bay and its tributaries. Many areas became denuded of SAV at this time and remain so today. This did not occur in the Lynnhaven River, where small SAV beds recovered within a few years and persisted at varying locations and extents until 2005, when another die off occurred. Some recovery has occurred in the Bay.

The SAV declines in the Chesapeake Bay and its tributaries have been caused primarily by three phenomena historically, and a fourth new problem: (1) runoff of agricultural herbicides, (2) erosional inputs of fine-grain sediments, (3) nutrient enrichment, as well as associated algal growth and anoxia, and (4) increasing water temperatures, which are causing larger and more frequent summer die-backs of eelgrass. Secondary factors include direct removal of SAV for use as packing material for fresh seafood; damage to SAV beds by clam dredging; damage to SAV beds by boat traffic, both commercial and recreational; and loss of protected areas due to erosion of protecting coves, islands, and other landmasses.

To provide incremental measures of progress, the Chesapeake Bay Program has established a tiered approach to SAV restoration in the form of targets for the Chesapeake Bay. The Tier I goal for the Lynnhaven River segment, which comprises the entire Basin, is 175.0 acres (Orth et al. 2003), which has not been met since aerial monitoring efforts were initiated in the 1970's. Tier I is considered the best habitat within the one meter contour (presence of SAV has been documented in these areas in recent (post 1971) years. The Tier II target, which corresponds with the one meter (3.28 ft) contour, is 1,337 acres, and the Tier III target, which corresponds with the two meter (6.56 ft) contour, is 1,603 acres.

According to the most recent information collected by VIMS on the 2010 distribution of SAV in the Chesapeake Bay, several small beds exist in the vicinity of Broad Bay, with the largest bed in the southeast corner of Broad Bay. These are the first beds larger than one acre seen in the Lynnhaven since 2005. Species composition of the beds is reported as widgeon grass (*Ruppia maritima*) and eelgrass (*Zostera marina*) (Orth et al., 2003).

2.2.6 Bay Scallops. Seaside lagoons once provided habitat for Bay Scallops until the 1930's when the habitat was destroyed by the "Storm King" hurricane (Seitz et al. 2009) and subsequent SAV die off. Since that time, scallops have not been present in the Lynnhaven Bay system or other former habitat along Virginia's lower Eastern Shore. There are no known scallop populations large enough to encourage recruitment to the area in any numbers. Left alone, it is unlikely scallops will recolonize the Lynnhaven Bay River system or any other nearby habitat.

2.2.7 Wetlands. The Lynnhaven River is a uniquely valuable ecological resource because the Basin contains the largest estuary in the City of Virginia Beach. Tidal wetlands, also called salt marshes, are areas between the land and ocean that periodically become flooded with salt or brackish water due to tidal action. These areas are typically covered with dense stands of salt-tolerant plants. Wetlands perform many essential environmental functions, such as buffering the shore from erosion caused by boat wakes, providing habitat for terrestrial and aquatic organisms, and filtering upland runoff, among others. As Virginia Beach has developed into an urban center, the acreage of wetland habitat in the Lynnhaven River has decreased, similar to losses experienced nationwide. Therefore, the remaining tidal wetlands are extremely important to the ecological integrity of the system.

More than half of the salt marshes in the United States have been lost. The Lynnhaven system has also experienced large amounts of tidal wetlands losses. An early survey of wetland resources within the project area was completed in 1979 by Barnard and Doumlele. This study described 860 acres of tidal wetlands present within the Basin. Most salt marshes observed during this survey were described as fringe marshes, which are narrow bands of salt marsh usually less than 33 feet in width, and pocket marshes that were dominated by wetland plant species, specifically saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow grasses (*Spartina patens* and *Distichlis spicata*), black needlerush (*Juncus roemerianus*), and saltbushes (*Iva frutescens* and *Baccharis halimifolia*), that are typically found in marshy areas of the Atlantic Coast. The authors of the report noted that the marshes in the Lynnhaven Basin were under stress from human activities and that some areas, notably within Linkhorn Bay, were highly developed and extensively bulkheaded.

The most recent wetland survey of the Lynnhaven Basin, completed in 2007, concludes that the tidal wetlands have been altered in size and shape through development, storms, and climate change since the 1979 survey (Berman, 2009). In total, 699.3 acres of tidal wetlands still remain in the Lynnhaven Basin. The report describes a larger area of shoreline (approximately 29 percent when marsh islands were excluded from the calculations) had been hardened through the use of bulkhead, riprap, or some other engineered protections. Even with the increase in development, the Lynnhaven Basin still contained several extensive marsh complexes. The largest concentration of tidal wetlands was found at the headwaters of the Western Branch. Marsh islands and fringe marshes are now the two most common marsh configurations.

Marsh islands are one of the two most prevalent marsh types (in addition to fringe marshes) that make up the extant tidal wetlands within the Lynnhaven Basin. As the name implies, marsh islands are isolated areas of marsh that are surrounded on all sides by open water. The islands may contain areas of both high and low marsh plant communities and even trees at the highest elevations of the interior sections. In the 1979 survey of tidal wetlands in the Lynnhaven Basin, over 130 acres of marsh islands were identified (Barnard and Doumlele 1979). In a more recent study completed in which VIMS analyzed the impact of sea level rise on the tidal wetlands in the Lynnhaven Basin, it is predicted that the majority of marsh islands would be lost by 2100 if sea level rise increases to .289 inches (7.35 mm) per year (Berman, 2009). More detailed discussion of potential sea level rise is found is section 2.2.10.

In addition to shoreline stabilization efforts, such as bulkheads and riprap, large areas of tidal wetlands have been lost through the installation of small, privately owned dams. These dams were constructed for a variety of reasons including the creation of farm ponds in the late nineteenth century, recreational uses, aesthetics, and stormwater impoundments which all create small, shallow, brackish lakes. More than 20 of these dams are located within the Lynnhaven Basin.

Another negative and well documented trend within marsh ecosystems along the northern and middle Atlantic Coast of the United States has occurred relatively recently. Native plants have been replaced by an invasive species, *Phragmites*, also known as common reed, over the last several decades (Havens et al., 1997; Chambers et al., 1999; Amsberry et al., 2000; Meyerson et al., 2000; Weinstein et al., 2000). Although fossil records have demonstrated that *Phragmites* has been present in the United States since the Cretaceous Period (Berry, 1914; Lamotte, 1952), the abundance and range of *Phragmites* have increased dramatically since the 1900's (Rice et al., 2000). Recently, two separate genotypes of common reed, a form native to North America and a European form, have been identified. It is the second of these lineages or the European form which is the more invasive and is responsible for the dramatic expansion of *Phragmites* throughout the East Coast (Saltonstall, 2002).

Phragmites invades disturbed areas more readily than undisturbed sites. Both natural disturbances, such as storms and wave action, and human activities, such as soil exposure and vegetation removal, provide opportunities for invasion. Once established, *Phragmites* often spreads rapidly because it has a number of advantages over the native grass species, including a longer growing season and the ability to alter marsh ecosystem to meet the species' optimal growing conditions. The plant is extremely difficult to eradicate from a site. The plant can propagate from either seed or rhizomes, and it produces a thick mat of rhizomes which will continue to sprout if not entirely removed.

2.2.8 Aquatic Fauna.

2.2.8.1 ***Commercial Benthos*** - The Lynnhaven River once supported a productive oyster fishery and the world renowned "Lynnhaven Fancy" was an important component of the local economy. According to the Virginia Oyster Heritage Program, the peak of Virginia's oyster harvesting occurred in the 1900's, when annual catches exceeded nine million bushels. Production from leased oyster grounds in the Lynnhaven approached 400,000 pounds per year from 1929-1930; however, by 1931, small portions of the system were being condemned for direct market due to bacteria levels (Neilson, 1976). By 1958, landings had decreased to four million bushels and by 1975, the entire Lynnhaven estuary was under shellfish condemnation, due to unacceptably high fecal coliform levels. Since that time, small areas have been reopened and closed periodically, namely in the Broad Bay/Linkhorn Bay area (Hayes et al., 1988). Total landings for the 1997-1998 season were 14,295 bushels, only one percent of the catch from a few decades earlier (Virginia Oyster Heritage Program, 1999). The loss of the oyster industry of the Lynnhaven system can be attributed to degraded water quality and oyster disease combined with the effects of overharvesting.

In addition to the loss of the oyster industry, overharvesting, disease, and decreased water quality has caused the destruction of an essential aquatic habitat type within the Lynnhaven River Basin. Aquatic reef, also referred to as oyster reef or fish reef in this report, is an ecological community made up of densely packed oysters. The oysters create three dimensional hard surfaces over the ocean bottom that provide habitat for a complex and diverse community that includes both fish and invertebrates. Barnacles and mussels attach themselves to the oyster shells, while crabs and flatworms live in the interstitial spaces between the oysters. Fish such as gobies, blennies, toadfish, and skilletfish spend the majority of their lives in the reefs; while white perch, striped bass, and blue crabs visit the reefs to feed. Very high densities of fish are found around reefs. Various oyster harvest techniques developed in the 1800's, such as mechanical oyster dredges brought in by New England oystermen, steamboats, and steam engine operated equipment, cause extensive damage to the reefs. These larger dredges and more advanced equipment destroyed the complex structure of oyster reefs, resulting in flat beds of oysters distributed on thin layers of shell or "cultch" scattered over the open sea bottom. With the loss of reef habitat, the majority of bottom in the Lynnhaven system consists of soft sediment, with very little structure.

Recently, water quality has begun to improve, and in 2008, the Virginia Department of Health opened 1462 acres of the Lynnhaven, approximately 29 percent of the area of the entire Basin, to shellfishing. This opened some areas to shellfishing for the first time since the 1930's (Virginia Department of Health, 2009).

To date, a number of successful oyster habitat restoration projects have occurred in the Lynnhaven. Two sanctuary reefs constructed by the Chesapeake Bay Foundation are present in the Long Creek/Broad Bay/Linkhorn Bay complex. The USACE, Norfolk District constructed approximately 28 acres of oyster reefs in 2007 and an additional 30 acres of new reefs in 2008, establishing a large oyster sanctuary refuge within the Lynnhaven system.

In addition to oysters, three other shellfish species, the hard shell clam (*Mercenaria mercenaria*), conch, and blue crabs (*Callinectes sapidus*), have been harvested from the Lynnhaven River Basin. Approximately 280,000 pounds of blue crabs, 680 pounds of conch, and 17,000 pounds, both public and private, of hard shell clams were landed in 2008.

2.2.8.2 ***Noncommercial Benthos*** **-** Benthic, or bottom living, invertebrates that are not harvested commercially are often studied extensively. Similar to the "canary in a coal mine", these creatures can be used to assess the current environmental conditions of an area, because they respond predictably to both natural and anthropogenic stressors. A significant amount of information has been gathered about the benthic communities present in the Lynnhaven River Basin. Dr. Daniel M. Dauer of Old Dominion University completed numerous studies on the subject in the late 1970's and the early 1980's. More recent studies investigating the invertebrate population include an Environmental

Assessment (EA) of the Western Branch of the Lynnhaven River, completed in 1993, and a survey commissioned by USACE, Norfolk District in 2007.

Between 1979 and 1982, Dr. Dauer published six papers describing the benthic community of the Lynnhaven River. Dauer found that the most important factor controlling the spatial distribution of invertebrate species within the Lynnhaven Basin was sediment type. "The Lynnhaven Bay system can be divided into organisms which are restricted to sandy substrates and organisms which occur over a wide variety of substrate types (Touretellotte and Dauer, 1983)." And that sites with mud substrates closer to the headwaters generally supported lower densities, lower average abundance, and lower biomass of benthic species than sites with sandier substrates (Dauer et al., 1979). Dauer and his associates also concluded that increased habitat diversity (Dauer et al., 1982b) or the exclusion of large predators (Dauer et al., 1982a) will result in significantly higher total densities of the benthic organisms. Between 45 (Dauer et al., 1979) and 153 (Touretellotte and Dauer, 1983) different species were collected during each study. The majority of animals gathered were annelids (round worms), however arthropods (crabs, shrimp, etc.), mollusks (clams, snails, etc), cnidaria (sea anemones, etc.), and flat worms were also found. The species list from each study is included in Table C-1 of the Environmental Appendix of this report.

An EA describing the benthic community inhabiting the Western Branch of the Lynnhaven River and its tributaries was completed by Maguire Associates in 1993 for the City of Virginia Beach (Maguire Associates, 1993). Similar to findings of Dauer's studies, results of that sampling event indicate that the benthic community is dominated by a variety of annelid worms. Maguire Associates also concluded that, when compared to models used by the Chesapeake Bay Program, the Western Branch supports the same or higher than expected levels of animal abundance but lower than expected values for community biomass.

Most recently, a survey of the benthic community within Lynnhaven River was completed for the USACE, Norfolk District (Dauer, 2007). 135 species were collected during the 2007 survey; the majority of which were polychaete worms. A complete list of all species collected during the study can be found in Table C-1 of the Environmental Appendix.

Using a Benthic Index of Biological Integrity (BIBI), the diversity and density of the benthic community was used as a proxy to determine the condition of project sites (Dauer, 2007). The average BIBI value calculated for all sites is 2.1, meaning that on average areas within the Lynnhaven Basin were "Degraded." The Inlet area received the highest average IBI value of 2.9, or a "Marginal" rating, while a sample site within the Linkhorn Bay–Crystal Lake area had the lowest average BIBI score of 1.6, indicating the area is "Severely Degraded." The authors of the 2007 study concluded that the main stressors on the Basin were "nutrient enrichment from storm water runoff, contaminants (organic and metal) from impervious surface runoff, and storm water runoff and siltation from land runoff that has altered bottom sediment types and represents a challenge for the restoration and development of shellfish species."

2.2.8.3 ***Freshwater Invertebrates*** - A single species of freshwater mussel, eastern elliptio mussel (*Elliptio complanata*), and two species of freshwater crayfish, the white river crayfish (*Procambarus acutus*) and a crayfish without a common name (*Cambarus acuminatus*), are found within three miles of the inlet to the Lynnhaven River Basin (VDGIF, 2010) (Table C-2).

2.2.8.4 ***Fish*** - According to the Virginia Department of Game and Inland Fisheries' (VDGIF) online database, Fish and Wildlife Information Service (FWIS), several species of anadromous fish may potentially occur in the vicinity of Lynnhaven Inlet. These include Atlantic sturgeon (*Acipenser oxyrhynchus*), a state species of special concern that is currently under review for Federal listing, alewife (*Alosa pseudoharengus*), and gizzard shad (*Dorosoma cepedianum*). The catadromous fish, the American eel (*Anguilla rostrata*), is also found in the Lynnhaven River Basin. A few of the other fish species either documented or expected to occur within the project area include banded killifish (*Fundulus diaphanus*), largemouth bass (*Micropterus salmoides*), spot (*Leiostomus xanthurus*), marsh killifish (*Fundulus confluentus*), and chain pickerel (*Esox niger*). Table C-3 includes a complete list of species identified within 3 miles of Lynnhaven Inlet (VDGIF, 2010).

Historically, 53 species of fish have been documented as occurring in the Lynnhaven River system (Malcolm Pirnie, 1980). A fish survey was conducted on 22 February 1992 in the Western Branch (Maguire Associates, 1993) that documented ten species. Due to the timing of the sampling event, the species identified were almost all juveniles of resident species. Five of these species are considered of commercial and recreational importance, namely hogchoker (*Trinectes maculatus*), striped mullet (*Mugil cephalus*), red drum (*Sciaenops ocellatus*), and windowpane flounder (*Scophthalmus aquosus*). The remaining five species are considered important prey species, including Atlantic silverside (*Menidia menidia*), bay anchovy (*Anchoa mitchelli*), mummichog (*Fundulus heteroclitus*), sheepshead minnow (*Cyprinodon variegatus*), and striped killifish (*Fundulus majalis*). Atlantic silverside was the most abundant species.

A survey of the Eastern Branch of the Lynnhaven River conducted in October 1988 identified seven fish species (Hayes et al., 1988). These species included menhaden (*Brevoortia tyrannus*), sheepshead minnow, striped killifish, spot (*Leiostomus xanthurus*), white perch (*Morone americana*), white mullet (*Mugil curema*), and striped mullet (*Mugil cephalus*). Menhaden was the most abundant species.

In 2007, a survey designed to assess the impacts of dredging on fish communities within tidal creeks located in the Lynnhaven Basin was completed by VIMS for the USACE, Norfolk District. The study sampled three paired tidal creeks, one dredged and the other undredged, on three separate occasions in August, September, and October. The study concluded that the "tidal creeks within the Lynnhaven Bay supports diverse and similar fish communities." The differences in communities were attributed to location and size of the Basin and not to dredging. In all, 30 nektonic species were collected from the six creeks (Table C-4). 90 percent of the samples were made up of Atlantic silversides (*Menidia menidia),* bay anchovy (*Anchoa mitchilli*), gizzard shad

(*Dorosoma cepedianum*), silver perch (*Bairdiella chrysoura*), and Atlantic menhaden (*Brevoortia tyrannus*) (Bilkovic et al., 2007).

The authors of the 2007 survey found that their results showed similar levels of species diversity as a study performed by Schauss in 1977, which compiled 31 species through beach seine and plankton collections. The 1977 survey concluded that the Lynnhaven River served as significant nursery grounds for species including bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), white mullet (*Mugil curema*), Gobiosoma spp. (goby), and green goby.

There were notable differences in fish communities described in the 2007 survey compared to older study. For example, Atlantic menhaden (*Alosa pseudoharengus*), gizzard shad (*Dorosoma cepedianum*), white perch (*Morone americana*), and silver perch (*Bairdiella chrysoura*) were absent or in low abundance in the 1977 survey but were prevalent in the 2007. While sheepshead minnow (*Cyprinodon variegatus*), spotfin mojarra (*Eucinostomus argenteus*), striped killifish (*Fundulus majalis*), naked goby (*Gobiosoma bosc*), and blackcheek tonguefish (*Symphurus plagiusa*) were more common in the older survey than observed in 2007. The authors of the more recent survey conjectured that this change in fish community was due to a reduction in marsh and oyster reef habitats within the Lynnhaven system (Bilkovic et al., 2007).

VMRC has collected data on the landings which occur in waters of Virginia from 1978 to the present. During 2008, the most recent landing data available, more than 156,000 pounds of fin fish, valued at approximately $62,000 were reported to have been taken from the Lynnhaven River Basin. The species that were harvested include bluefish (1,954 lbs), butterfish (124 lbs), catfish (12 lbs), cobia (33 lbs), Atlantic croaker (86,501 lbs), American eel (700 lbs), American flounder (211 lbs), menhaden (11,283 lbs), minnow (768 lbs), mullet (710 lbs), porgy (75 lbs), northern puffer (18 lbs), red drum (18 lbs), king whiting (2,127 lbs), spiny dogfish (24 lbs), saltwater sheepshead (10 lbs), Spanish mackerel (31 lbs), spot (16,312 lbs), spotted seatrout (10 lbs), striped bass (11,064 lbs), oyster toadfish (5 lbs), and grey seatrout (1,261 lbs). Species which were not caught in 2008, but have been landed in Lynnhaven during past years, include Atlantic herring, Atlantic mackerel, black seabass, blacktip shark, common pompano, dusky shark, false albacore tuna, gizzard shad, hickory shad, pigfish, scup, tautog, and thresher shark (Virginia Marine Resource Commission, 2010).

Many species of fish rely on oyster reefs for all or part of their lifecycle. Oyster reefs provide food, habitat for juveniles, and enhance survival by providing structural refuges from predators. Certain species and species groups, such as gobies, blennies, sheepshead, and toadfish, are exclusively associated with reef habitat (Peterson et al. 2003). Densities of these fish are found to be considerably higher on reefs than on unstructured mud or sand bottoms. While other species such as black seabass, sheepshead minnow, bay anchovy, and silversides are also found to aggregate around hard reef structure, they do not spend their entire lives associated with oyster reefs. In the 2003 study, Peterson *et al.* concluded that 19 species of fish and large mobile crustaceans from Virginia to Florida were more abundant around oyster reef habitat.

Even with the uncertainties associated with success of man-made oyster reefs, Peterson *et al.* estimated that the productivity fish and large invertebrate associated with the restoration of oyster reefs would increase by 38.2 kg 10 m^{-2} by year 20 of the reef and 50.4 kg 10 m^{-2} 30 years after the construction of the oyster reefs, once taking into consideration of a three percent discount rate. In 1894, Lieutenant James B. Baylor surveyed the oyster reefs within the Lynnhaven River Basin for the Commonwealth of Virginia. At that time, 986 acres of oyster reef existed within the Basin. Today, there are approximately 63 acres of oyster reef in the Basin.

2.2.9 <u>Essential Fish Habitat</u>. The Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), requires all Federal agencies to consult with the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect Essential Fish Habitat (EFH). EFH has been designated for waters within the Chesapeake Bay (area designated by the limits North 37°00.0 N, East 76°00.0 W, South

36°50.0 N and west 76°10.0 W) including the area of Lynnhaven Inlet and Bay for 19fish, including three skate species, which are listed in Table 1 (NOAA, 2010). The "NMFS Essential Fish Habitat Designations" section in the Environmental Appendix described these species and EFH associated with each.

Table 1. NMFS LISTED FISH SPECIES WITH ESSENTIAL FISH HABITAT AND THE SPECIFIC LIFE PHASE OCCURING WITHIN THE LYNNHAVEN RIVER

Common Name	Scientific Name	Eggs	Larvae	Juveniles	Adults
red hake	*Urophycis chuss*	-	-	X	X
windowpane flounder	*Scopthalmus aquosus*	-	-	X	X
Atlantic sea herring	*Clupea harengus*	-	-		X
bluefish	*Pomatomus saltatrix*	-	-	X	X
Atlantic butterfish	*Peprilus triacanthus*	X	X	X	X
summer flounder	*Paralicthys dentatus*	-	X	X	X
Scup	*Stenotomus chrysops*	-	-	X	X
black sea bass	*Centropristus striata*	-	-	X	X
king mackerel	*Scomberomorus cavalla*	X	X	X	X
Spanish mackerel	*Scomberomorus maculatus*	X	X	X	X
Cobia	*Rachycentron canadum*	X	X	X	X
red drum	*Sciaenops occelatus*	X	X	X	X
sand tiger shark	*Odontaspis Taurus*	-	X	-	X
Atlantic sharpnose shark	*Rhizopriondon terraenovea*	-	-	-	X
dusky shark	*Charcharinus obscurus*	-	X	X	-
sandbar shark	*Charcharinus plumbeus*	-	X	X	X
clear nose skate	*Raja eglanteria*	-	-	X	X
little skate	*Leucoraja erinacea*	-	-	X	X
winter skate	*Leucoraja ocellata*	-	-	X	X

2.2.10 <u>Sea Level Change</u>. Sea level change (SLC) is predicted to continue in the future as the global climate warms. A recent study by VIMS, conducted for the Norfolk District, "Chesapeake Bay Land Subsidence and Sea Level Change" (Boone et al., 2010, http://www.vims.edu/newsandevents/_redirects/boon_sea_level_study.php) predicts a change in relative sea level rise ranging from 0.114 inches/year to 0.22 inches/year in the

Chesapeake Bay. This equates to approximately one half foot of SLC to one foot of SLC over the next 50 years. Additionally, USACE recently issued EC 1165-2-212, "Incorporating Sea-Level Change Considerations in Civil Works Program." This USACE guidance provides three different accelerating eustatic SLC scenarios including a conservative scenario (historic rate of sea level rise), an intermediate scenario, and a high scenario. The scenarios presented in the USACE guidance estimate SLC thru 2064 to be 0.73 feet for the conservative approach, 1.14 feet for the intermediate approach and 2.48 feet for the high scenario.

2.3 Water Quality

2.3.1 Current Water Quality. The Clean Water Act (CWA) establishes the basic structure for regulating surface waters quality. The CWA requires each state to establish water quality standards for all bodies of water in its boundaries. Individual reaches within the Lynnhaven River Basin do not meet current designated uses and are included in the draft 2012 305(b)/303(d) Water Quality Assessment Integrated Report for the commonwealth of Virginia (DEQ 2012). Table 2 lists the impairments reported within the Lynnhaven River, the size of the impairment, the potential origin of the impairment, and the current standard the state uses to judge whether the water body is impaired.

In addition to impairments specific to the Lynnhaven River Basin, the city of Virginia Beach must also meet the requirements of the TMDL limits for sediment and the nutrients nitrogen and phosphorus established by the USEPA for the entirety of the Chesapeake Bay. Nutrients, i.e. nitrogen and phosphorus, continue to enter the system mainly through storm water runoff. The sources of nutrients in the Lynnhaven River System are lawn and garden fertilizer as well as pet and wildlife wastes. Nitrogen is also air deposited in the river with cars as the primary source in the Lynnhaven watershed. Once in the water column, excess nutrients negatively impact water quality because they promote algae growth and algal blooms which reduce water clarity and reduce the dissolved oxygen in the water. Sediment enters a river system thorough many paths, including bank erosion and stormwater. High concentrations of suspended sediment will reduce water clarity and can smother benthic organisms as the sediment settles out of the water column. Water clarity is essential for SAV, which provide critical water filtration and animal habitat in a healthy aquatic ecosystem.

Table 2: LIST OF IMPAIRED WATERS INCLUDED IN THE VIRGINIA DEQ DRAFT 2012 305(B)/303(D) WATER QUALITY ASSESSMENT INTERGRATED REPORT THAT ARE LOCATED IN THE LYNNHAVEN RIVER BASIN

Parameter	Designated Use	Area	Current Standard	Origin
PCB in Fish Tissue	Fish Consumption	.74 sq miles in the Eastern Branch		Source Unknown
Dissolved Oxygen	Aquatic Life	7.09 sq miles of the watershed	30-day mean $\geq$ 5.5 mg/l - growth of tidal-fresh juvemiles/adult fish, 7-day mean $\geq$ 4 mg/ l- survival of open-water fish larvae, Instantaneous minimun $\geq$ 3.2 mg/l - survival/recruitment of T/E sturgeon species	Agriculture, Atmospheric deposition (nitrogen), Industrial point source discharge, Internal nutrient recycling, Loss of riparian habitat, Municipal point source discharges, Sources outside of state jurisdiction or borders, Wet weather discharges.
Enterococcus contamination	Recreational Usage	0.84 square miles of the Lynnhaven Basin. Sections of Thalia Creek, Thurston Branch, Buchanan Creek, Western Branch, London Bridge Creek and Eastern Branch	104 individuals per 100 ml	Source Unknown
Fecal Coliform Contamination	Shellfishing	2.99 square miles, including Sections of Dey Cove, Mill Dam Creek, Broad Bay, Linkhorn Bay, Long Creek, Little Neck Creek and the Lynnhaven River	14 FC bacteria per 100 milliliters of water	Discharging from municipal storm sewer systems, Natural sources, Non-point sources, Septic systems and similar decentralized systems, Unknown sources
Benthic-BIBI (species diversity)	Aquatic Life	7.09 sq. miles of the watershed	B-IBI Scores >2.7	Unknown Contaminated Sediments

The City of Virginia Beach has taken steps to meet the newly established Chesapeake Bay TMDL's by commissioning a study that determined the required reduction for each pollutant, i.e. phosphorus, nitrogen, and total suspended solids (TSS), that the City must achieve in order to comply with the EPA's 2025 Waste Load Allocation (WLA) (Kimley-Horn 2011). The pollutant load was estimated using 2009 land coverage data. Without including the pollutant reduction resulting from currently existing stormwater Best Management Practices (BMP) installed in the system, study found that the phosphorus load in the Lynnhaven River Basin was only slightly greater than the 2025 target. 2,217 pounds/year of total phosphorus would have to be removed from the Lynnhaven System in order to meet the WLA. The other two pollutants require greater reductions. 126,280 pounds/year of total nitrogen and 5,243,121 pounds/year of TSS would have to be eliminated from the system to meet the USEPA's WLA.

2.3.2 <u>Water Quality Projects Within the Lynnhaven Basin</u>. A number of organizations have recognized the value of the Lynnhaven River system and have implemented projects to restore the Lynnhaven River Basin. The two most prominent groups in this effort are the City of Virginia Beach and Lynnhaven River NOW. Current efforts are directed towards achieving a river that is unimpaired and is able to meet all of the designated uses set by the Commonwealth of Virginia. The cumulative effect of all of the actions being taken now and in the future would be improved water and habitat quality.

Virginia Beach, together with Lynnhaven River NOW, petitioned the USEPA through the VDEQ to designate the entire Lynnhaven River Basin as a "No Discharge Zone." This designation went into effect in 2007 and forbade boats to discharge wastewater into the river. It is the first tidal river in Virginia to have this designation and only the second river in the Commonwealth to be designated as such. In addition to the designation, the city has initiated the "Boater Education and Pump Out Program", established pump out facilities, and provided pump out teams through the summer boating season. The city continues to promote this program through television advertisements and boater education classes.

By reducing the amount of untreated or undertreated wastewater discharged by recreational boaters, the city simultaneously addresses many of the current water quality impairments. The amount of fecal coliform, the standard used by the USEPA to determine if waters can sustain shellfish harvesting and consumption, entering the system has been significantly reduced. The same can be said of the amount of enterococcus, the USEPA's standard for determining primary recreational use. Reducing the amount of untreated waste from boaters also decreases the biochemical oxygen demand (BOD), which is the measure of oxygen required to stabilize the decomposable matter present in the waste by aerobic biochemical action. Spills or discharges of poorly treated or untreated wastewater into confined or poorly flushed areas increase the BOD and increase the chances that the water will become hypoxic or anoxic. Finally, quantities of nutrients, such as nitrogen and phosphorus, which were introduced into the system through boat discharges, have been dramatically reduced.

Since the 1970's, the City of Virginia Beach has also reduced the amount of untreated sewage entering the Lynnhaven system through improvements to sewage treatment in the communities surrounding the Lynnhaven River. Since 2003, the city has invested $71.3 million in upgrades to the sanitary sewer system. These efforts included the elimination of septic tank usage. By 2010, all but 229 of the original 11,600 septic tanks have been eliminated from the system.

In 2007, the city took an important step towards addressing releases of untreated sewage from the sanitary sewer system. Virginia Beach entered into a Special Order by Consent (SOC) with the VDEQ, Hampton Roads Sanitation District (HRSD) and other area localities for the purpose of resolving Sanitary Sewer Overflows (SSOs). This agreement required the city to perform the following:

1. Prepare a Sanitary Sewer Evaluation Survey (SSES) Plan.
2. Perform interim repairs to existing facilities that require prompt attention under the provisions of the Regional Technical Standards (RTS).
3. Conduct interim system improvements in conformance with the RTS.

4. Coordinate with HRSD to develop a Regional Hydraulic Model.
5. Develop a calibrated hydrologic and hydraulic model of the City's sanitary sewer system.
6. Prepare a Management, Operations and Maintenance (MOM) Program.
7. Promptly report all sewage discharges in accordance with the Hampton Roads SSO Reporting System.
8. Submit an Annual Report to DEQ.

Since Virginia Beach entered the SOC, there has been a steady reduction of SSOs. In fiscal year (FY) 2006 a total of 81 SSOs were reported. In FY 2011, five years after the implementation of the program, that number was reduced to15. The incidence of reportable SSOs the city experienced in FY 2011 decreased by 55 percent from 2010 and by 81 percent from 2006. By connecting citizens to the sanitary sewer system and reducing the number of SSOs, the city has reduced the amount of pollutants, including FC, enterococcus bacteria, phosphorus, and nitrogen that degrade water quality.

The City of Virginia Beach has also taken steps to improve the quality of stormwater entering the Lynnhaven River System. Since 2003 the city has spent $60.2 million to expand its stormwater system. As of 2011, there are 1,100 outfalls located in the Lynnhaven Basin. The city currently uses solar aeration, bacterra and filterra units, dry and wet ponds, and BMP's to reduce the amount of bacteria, sediment, and nutrients from the stormwater running into the river. In addition, hydrodynamic separators have been installed at five stormwater outfalls. Although the hydrodynamic separators don't completely address pollutant inputs due to stormwater runoff, this equipment reduces the sediment-carrying ability of storm water.

Other actions to improve the Lynnhaven River Basin initiated by the city include the completion of a Comprehensive Stormwater Management Plan in 2010, a study that identified over a million dollars of water quality retrofits. The city also requires strict construction BMP's for construction adjacent to the river and has obtained parcels such as Pleasure House Point (over 100 acres) in order to set the land aside as nature preserves.

Lynnhaven River NOW has sponsored several programs in the Basin aimed at environmental improvement. The oyster gardening program, in concert with the Chesapeake Bay Foundation, teaches citizens through workshops how to oyster garden, provides the oyster seed for gardening, and transplants the oysters from the oyster gardeners to conservation reefs. The Chesapeake Bay Foundation and Lynnhaven River NOW also partner with the City of Virginia Beach in a program to recycle oyster shell. This program collects shell from oyster roasts and seafood festivals and provides shell drop off locations for citizens and restaurants to use. The shell acquired through this program is then used in the construction of oyster reefs.

Partnering with the city, Lynnhaven River NOW has also conducted an extensive, ongoing education campaign that included installing watershed and storm drain identification markers and conducting a campaign targeted at pet waste management.

Lynnhaven River NOW actively partners with schools, both public and private, located within or serving students from the City of Virginia Beach, to provide presentations and programs emphasizing water quality education and environmentally focused curriculums. They also offer schools on site learning projects which focus on improving water quality, such as rain barrels, "Scoop the Poop" boxes, rain gardens, buffer gardens, and oyster gardening. Lynnhaven River NOW recognizes schools that provide outstanding environmental education through it's "Pearl School Award" program.

Each year Lynnhaven River NOW issues a state of the river report. The report provides grades on different aspects of pollution, pollution control, habitat, and awareness of issues within the Lynnhaven River Basin. The reports have been issued every year since 2005.

The Chesapeake Bay Foundation is another organization that is currently addressing the ecosystem restoration challenges posed by the Chesapeake Bay. The Chesapeake Bay Foundation has partnered with Lynnhaven River NOW and the City of Virginia Beach to construct oyster reefs within the Lynnhaven River.

Oyster restoration in the Lynnhaven River has been ongoing since 1997 and the system currently has 63 acres of conservation oyster reefs. As filter feeders, oysters play an important role in the improving and maintaining aquatic habitat and water quality. A recent study completed by VIMS in December 31, 2011 determined that an acre of oyster reefs in the Lynnhaven River Basin typically removes approximately 200 pounds of nitrogen per year. The existing conservation oyster beds are supported through oyster gardening program directed by Lynnhaven River NOW, described previously.

A new initiative to improve water quality in the Lynnhaven is the harvesting of phragmites. The City partnered with USACE Norfolk District to complete a Section 22 study on the potential for using phragmites harvesting as a BMP for TMDLs, with positive results. The City is currently petitioning the Chesapeake Bay Program Coordinator of the Virginia Department of Conservation and Recreation to use the harvesting of phragmites as a BMP.

2.3.3 Water Quality Trends. Although sections of the Lynnhaven River system are included in the 2012 list of impaired waters, there are signs that surface water quality is improving in the Lynnhaven River. For example, the majority of the Lynnhaven River Basin has been delisted by the commonwealth of Virginia for PCB contamination of fish tissue. Currently, only an area within the Eastern Branch is considered impaired.

Large improvements have been made to the levels of bacterial contaminations within the Lynnhaven River. Only one percent of the river met the standard for shellfish consumption in 2005. But, by 2007, the Virginia Department of Health opened 1,462 acres of the river to shellfishing. An area that large has not been open to shellfish harvesting since 1931. Water quality has continued to improve in the watershed and an area of 2,047 acres, approximately 42 percent of the river, was open for shellfishing in 2011.

In previous surveys, SAV was completely extirpated from the Lynnhaven system, even though historically SAV grew in dense beds in the river. These beds were lost due to poor water quality. Water clarity is required for healthy SAV beds, but is diminished by algae blooms and high concentrations of suspended sediment in the water column. There has been some improvement in water clarity in the Lynnhaven River. In 2010, environmental conditions had improved enough to support 6.08 acres of SAV beds and continue to trend in a positive direction.. The District strongly believes that these improvement trends will continue and continued implementation of water quality projects by non-Federal entities will allow for successful restoration.

Intermittent occurrences of low dissolved oxygen (DO) have been recorded in the Lynnhaven River watershed during the summer season, which is the reason why the river is included in the 2012 list of impaired waters. Unfortunately, this condition is observed in most of Virginia's estuarine waters, the majority of which are also listed as impaired for DO due to occasional low readings during annual monitoring programs. Without sufficient levels of DO in the water column, aquatic organisms cannot survive. Since 2006, the area of the impairment within the Lynnhaven watershed has remained the same at 7.9 square miles.

2.4 Terrestrial Resources

2.4.1 Avian Resources. The open water and associated marshes of the Lynnhaven River and surrounding areas provide habitat for many North American waterfowl species, with fringe marshes providing areas for foraging and nesting. The Lynnhaven River Basin is located along the Atlantic flyway and serves as a stopping point for transients and wintering grounds for northern species. A waterfowl survey of the Western Branch was performed by Maguire Associates on 17 February 1992 and 25 species of birds were documented, including brant (*Branta bernicla*), American widgeon

(*Anas americana*), bufflehead (*Bucephala albeoloa*), and ring-billed gull (*Larus delawarensis*) (Maguire Associates, 1993).

According to the VDGIF online database, more than 200 species of birds have been either documented or determined likely to occur in the project area. These include a variety of shorebirds, wading birds, waterfowl, rails, and passerines. More than 30 species have been afforded state or Federal conservation status, including threatened and endangered species, species of special concern, and candidate species. Table C-5 lists bird species identified within a three mile radius of the Lynnhaven Inlet. Table C-9 includes state and Federally listed species, and Table C-10 includes species identified in the Virginia Wildlife Action Plan, which is described in further detail in the section entitled "Threatened and Endangered Species" (VDGIF, 2010).

2.4.2 Mammals. More than 40 species of mammals inhabit the area of the proposed project, most of which are small creatures such as mice, rats, squirrels, shrews, squirrels, rabbits, skunks, and voles. Larger mammals, which are more closely associated with uplands, within the Lynnhaven River Basin include white-tailed deer (*Odocoileus virginianus*), common grey fox (*Urocyon cinereoargenteus cinereoargenteus*), and coyote (*Canis latrans*). In addition, eight bat species, including the state endangered species Rafinesque's eastern big-eared bat (*Corynorhinus rafinesquii macrotis*), utilize the project site. Wetland habitats support populations of muskrat (*Ondatra zibethica*), nutria (*Myocastor coypus*), and raccoon (*Procyon lotor*). Table C-6 lists all of the mammal species that may occur in the project area (VDGIF, 2010).

2.4.3 Reptiles and Amphibians. A variety of reptiles and amphibians are reported to occur within the project area. Table C-7 lists more than 50 species of frogs, toads, tree frogs, salamanders, skinks, snakes, and turtles that may be found within a three mile radius of the Lynnhaven Inlet (VDGIF, 2010).

2.4.4 Terrestrial Invertebrates. More than ninety species of butterflies, moth, ticks, spiders, and flies have been described by the USFWS to inhabit an area encompassed by a three mile radius around the Lynnhaven Inlet. A list of those species in is Table C-8 (VDGIF, 2010).

The large number of bird species that utilized the Lynnhaven system for all or some of their lifecycle demonstrates the environmental significance of the Lynnhaven System for birds. Other terrestrial resources reflect the advanced development of the area surrounding the Lynnhaven River System. Animals which can adjust to a suburban landscape are present at the site.

2.5 Threatened and Endangered Species

2.5.1 <u>Federal Species</u>. VDGIF's online FWIS database lists several Federally-listed species that have either been documented to occur or potentially occur in the project area. These species include five that are listed as Federally-endangered/state-endangered, namely the red-cockaded woodpecker (*Picoides borealis*), roseate tern (*Sterna dougallii dougallii*), hawksbill sea turtle (*Eretmochelys imbricata*), Kemp's Ridley sea turtle (*Lepidochelys kempii*), and leatherback sea turtle (*Dermochelys coriacea*). The loggerhead sea turtle (*Caretta caretta*), piping plover (*Charadrius melodus*), and green sea turtle (*Chelonia mydas*) are listed as Federally-threatened/state-threatened. FWIS also lists three species of Federal special concern, including the bald eagle (*Haliaeetus leucocephalus*), the funnel-web spider (*Barronopsis jeffersi*), and the Duke's or scarce swamp skipper (*Euphyes dukesi*). The bald eagle is also listed as a state threatened species (VDGIF, 2010). The Red Knot (Calidris canutus rufa) is currently a Federal candidate species, but it is anticipated that this species will soon be listed as either threatened or endangered. In light of this change in classification, the impact to this species was also considered.

2.5.2 <u>State Species</u>. VDGIF describes nine state-listed endangered species and fourteen state-listed threatened species that either occur or potentially occur within the project area. 27 avian and four non-avian species have been designated as state special concern. The northern diamond-back terrapin (*Malaclemys terrapin terrapin*) and the spotted turtle (*Clemmys guttata*) were listed as collection concern species. Table 3 lists species that have been identified as state endangered (SE), state threatened (ST), state candidate (SC), collection concern (CC), and state special concern (SS) in addition to Federally listed endangered, threatened, and candidate species that may be found within three miles of the Lynnhaven inlet.

Table 3. THREATENED AND ENDANGERED SPECIES AND SPECIES OF SPECIAL OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

STATUS	COMMON NAME	SCIENTIFIC NAME
FE/SE	Woodpecker, red-cockaded	*Picoides borealis*
FE/SE	Tern, roseate	*Sterna dougallii dougallii*
FE/SE	Turtle, hawksbill (= carey) sea	*Eretmochelys imbricate*
FE/SE	Turtle, Kemp's (= Atlantic) Ridley sea	*Lepidochelys kempii*
FE/SE	Turtle, leatherback sea	*Dermochelys coriacea*
FT/ST	Turtle, loggerhead sea	*Caretta caretta*
FT/ST	Plover, piping	*Charadrius melodus*
FT/ST	Turtle, green sea	*Chelonia mydas*
SE	Turtle, eastern chicken	*Deirochelys reticularia reticularia*
SE	Plover, Wilson's	*Charadrius wilsonia*
SE	Bat, Rafinesque's eastern big-eared	*Corynorhinus rafinesquii macrotis*
SE	Rattlesnake, canebrake	*Crotalus horridus*
ST	Falcon, peregrine	*Falco peregrines*
ST	Sandpiper, upland	*Bartramia longicauda*
ST	Shrike, loggerhead	*Lanius ludovicianus*
ST	Sparrow, Henslow's	*Ammodramus henslowii*
ST	Tern, gull-billed	*Sterna nilotica*
ST	Treefrog, barking	*Hyla gratiosa*
ST	Lizard, eastern glass	*Ophisaurus ventralis*
FS/ST	Eagle, bald	*Haliaeetus leucocephalus*
ST	Shrew, Dismal Swamp southeastern	*Sorex longirostris fisheri*
ST	Falcon, Arctic peregrine	*Falco peregrinus tundrius*
ST	Shrike, migrant loggerhead	*Lanius ludovicianus migrans*
FS	Spider, funnel-web	*Barronopsis jeffersi*
FS	Skipper, Duke's (or scarce swamp)	*Euphyes dukesi*
SS	Crossbill, red	*Loxia curvirostra*
SS	Sturgeon, Atlantic	*Acipenser oxyrinchus*
SS	Toad, oak	*Anaxyrus quercicus*
SS	Heron, little blue	*Egretta caerulea caerulea*
SS	Owl, northern saw-whet	*Aegolius acadicus*

Table 3. THREATENED AND ENDANGERED SPECIES AND SPECIES OF SPECIAL OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (continued)

STATUS	COMMON NAME	SCIENTIFIC NAME
SS	Sparrow, saltmarsh sharp-tailed	*Ammodramus caudacutus*
SS	Tern, least	*Sterna antillarum*
SS	Warbler, Swainson's	*Limnothlypis swainsonii*
SS	Wren, winter	*Troglodytes troglodytes*
SS	Frog, carpenter	*Lithobates virgatipes*
SS	Harrier, northern	*Circus cyaneus*
SS	Heron, tricolored	*Egretta tricolor*
SS	Ibis, glossy	*Plegadis falcinellus*
SS	Night-heron, yellow-crowned	*Nyctanassa violacea violacea*
SS	Owl, barn	*Tyto alba pratincola*
SS	Wren, sedge	*Cistothorus platensis*
SS	Creeper, brown	*Certhia Americana*
SS	Tern, Forster's	*Sterna forsteri*
SS	Rabbit, marsh	*Sylvilagus palustris palustris*
SS	Dickcissel	*Spiza Americana*
SS	Egret, great	*Ardea alba egretta*
SS	Finch, purple	*Carpodacus purpureus*
SS	Kinglet, golden-crowned	*Regulus satrapa*
SS	Moorhen, common	*Gallinula chloropus cachinnans*
SS	Nuthatch, red-breasted	*Sitta Canadensis*
SS	Owl, long-eared	*Asio otus*
SS	Pelican, brown	*Pelecanus occidentalis carolinensis*
SS	Tern, Caspian	*Sterna caspia*
SS	Tern, sandwich	*Sterna sandvicensis acuflavidus*
SS	Thrush, hermit	*Catharus guttatus*
SS	Warbler, magnolia	*Dendroica magnolia*
SS	Mole, star-nosed	*Condylura cristata parva*
SS	Otter, northern river	*Lontra canadensis lataxina*
CC	Terrapin, northern diamond-backed	*Malaclemys terrapin terrapin*
FC	Red Knot	*Calidris canutus rufa*

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010.
KEY - FE=Federal Endangered; FT=Federal Threatened; SE=State Endangered; ST=State Threatened; FP=Federal Proposed; FC=Federal Candidate; FS=Federal Species of Concern; SC=State Candidate; CC=Collection Concern; SS=State Special Concern DEP = Depleted status under the Marine Mammal Protection Act (*status is not listed by VDGIF).

More than 130 species that are found within the Lynnhaven River Basin are included in Virginia's Wildlife Action Plan as having the greatest conservation need. The Action Plan outlines a ten year strategy for conserving not only the species highlighted in the plan but all wildlife in Virginia. Species found within the project site that are identified in Virginia's Wildlife Action Plan are listed in Table C-10 (VDGIF, 2010).

2.6 Air Quality

The USEPA is required to set air quality standards for pollutants considered harmful to public health and welfare. The Primary National Ambient Air Quality Standards (NAAQS) set limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility and prevention of damage to animals, crops, vegetation, and buildings. These standards have been established for the following six principal pollutants called criteria pollutants (as listed under Section 108 of the Clean Air Act):

- Carbon monoxide;
- Lead;
- Nitrogen dioxide;
- Ozone;
- Particulate matter, classified by size as follows:
    - An aerodynamic size less than or equal to 10 micrometers;
    - An aerodynamic size less than or equal to 2.5 micrometers;
- Sulfur dioxide.

The Lynnhaven project area lies within the limits of the independent City of Virginia Beach, Virginia. According to the VDEQ Air Regulations (Chapter 20, Section 203), the City of Virginia Beach is designated as a "maintenance area" with respect to eight hour ozone. Maintenance areas are those geographic regions that have had a history of nonattainment but are now consistently meeting NAAQS standards. To be redesignated from "nonattainment" to "maintenance" an area must both meet air quality standards and have a ten year plan for continuing to meet and maintain air quality standards and other requirements of the Clean Air Act. The air regulations (9 VAC 5-160 – Chapter 5, section 160) set out by the VDEQ require Federal agencies to prepare a conformity determination if the total of both direct and indirect emissions produced by a Federal action in a maintenance area exceeds 100 tons per year of nitrogen oxides (NOx) or volatile organic compounds (VOC).

2.7 Noise

Noise is defined as an undesirable or "unwanted sound." Noise affects the full range of human activities and must be considered in local and regional planning (NYDEC, 2001). Noise levels are measured in units called decibels. Since people cannot perceive all pitches or frequencies equally, noise production is frequently reported in A-weighted decibels, or dBA, where noise is weighted to correspond to human hearing.

While there is no Federal standard for allowable noise levels, several agencies have developed guidelines for acceptable noise levels. The Department of Housing and Urban Development Guidelines denote Day-Night Sound Levels or DNLs (a noise rating developed by the USEPA for specification of community noise from all sources) below 65 dBA as normally acceptable levels of exterior noise in residential areas. The Federal Aviation Administration (FAA) denotes a DNL of 65 dBA as the level of significant noise impact. Several other agencies, including the Federal Energy Regulatory Commission, use a DNL criterion of 55 dBA as the threshold for defining noise impacts in sparse suburban and rural residential areas (Schomer et al, 2001). The USACE Safety and Health Requirements Manual provides criteria for temporarily permissible noise exposure levels, for consideration of hearing protection, or for the need to administer sound reduction controls (Table 4).

Table 4. PERMISSIBLE NON-DEPARTMENT OF DEFENSE NOISE EXPOSURES

Duration/day (hours)	Noise level (dBA)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105

The City of Virginia Beach regulates noise through its Municipal Code, Title 12, Chapter 23, Article II, Noise. The code prohibits noise exceeding 55 dBA during the hours of 10:00 pm and 7:00 am when measured inside a private residence. During the day, noise that can be measured inside a private residence exceeding 65 dBA is prohibited between 7:00 am and 10:00 pm. In addition, certain construction equipment, including cranes, cannot be operated between the hours of 9:00 pm and 7:00 am. In order to comply with the Virginia Beach code, construction machinery would be operated for approximately 8 hours, generating noise only during the daytime (7 am-6 pm) when many residents are at work.

Land use immediately surrounding the Lynnhaven River is primarily residential in nature. Limited areas of commercial use are located where Shore Drive crosses the mouth of the river and in the upper reaches of the river where Virginia Beach Boulevard and Independence Boulevard, two major thoroughfares in Virginia Beach, cross tributaries of the Lynnhaven system. Additionally, a significant amount of parkland makes up the Lynnhaven shore. Noise levels in the majority of the study area are typical of residential and recreational activities. The sound level for a quiet residential area with light traffic is approximately 60 dBA, while parks have lower sound levels (from 35 to 45 dBA). Increased noise levels would be experienced near the urbanized areas due to traffic levels. A busy urban street can have a noise level between 65 dBA and 80 dBA during the day. Noise levels fluctuate on the water with the highest levels usually occurring during the spring and summer months due to increased tourism, boating, fishing, and coastal activities. Sources of noise in the Lynnhaven system include lawn maintenance equipment (e.g. lawn mowers and weed eaters), commercial and recreational boat traffic, and personal water craft.

2.8 Socio-Economic Resources

2.8.1 Population. Virginia Beach is part of the Norfolk-Virginia Beach-Newport News Metropolitan Statistical Area (MSA), the second largest urban area in the state of Virginia. This city is the largest one in the state with a 2000 population of 425,257, an 8.2 percent increase from 1990 (U.S. Census) and an average annual growth rate of 0.8 percent from 1990 to 2000. This rate of growth is about the same as that for the MSA as a whole and a significant decrease from the 50 percent growth that occurred in the city between 1980 and 1990. As of 2009, the city had an estimated population of 434,412, which indicates an average annual growth rate of 0.2 percent since 2000 (Weldon Cooper Center for Public Service, University of Virginia, 2010). This small growth rate indicates that Virginia Beach's population as a whole is leveling off as the growth rate slows. While Virginia Beach's earlier growth was fueled primarily by in-migration, the growth in the last 19 years has been the result of natural increase (more births than deaths). The migration trend has reversed itself with more people moving out than in.

Projections from the Virginia Employment Commission show Virginia Beach's population continuing to grow through the year 2030, reaching a figure of 493,095. This figure represents an average annual growth rate of 0.5 percent, which is somewhat lower than the projected rate of 0.8 through 2030 for the MSA.

2.8.2 Land Use. Virginia Beach consists of 248 square miles of land and 249 square miles of water, for a total of 497 square miles. Development in the city tends to be concentrated in the northern half of the city with the southern portion dominated by agricultural use and large forested tracts. The predominant land use for the developed portions of the city is suburban residential. Residential land uses consist of low to medium density single family dwellings located in the northern and central portions of the city with the higher density multi-family uses located along several of the city's main highways. In recent years, there has been a slight shift to multi-family housing units with new construction, especially in the Town Center area (City of Virginia Beach, 2009).

Commercial development consists of primarily low intensity, suburban style development located at major road intersections and along many of the city's primary arterials. It varies in size from small scale strip shopping centers to major malls, both of which tend to have large parking areas and out parcels with gas stations, convenience stores, and fast food restaurants. The two largest shopping areas are Lynnhaven and Pembroke Malls. In addition to the shopping areas, there are several concentrations of office use throughout the city.

Industrial development ranges from low to moderate intensity office industrial parks to several heavy industrial operations. The largest industrial park is the Oceana West Industrial Park, which contains approximately 1,024 acres. The heavy industry operations are scattered throughout the city, and these operations serve mainly as central offices and storage/repair yards for construction equipment and materials (City of Virginia Beach, 2009).

The second largest category of land use after residential is agricultural, which covers 30 percent of the total acreage as of 2007. Most of the agricultural land can be found in the southern part of the city. An additional 18 percent of the land is categorized as public or governmental (City of Virginia Beach, 2009).

2.8.3 Employment. Employment in Virginia Beach has been growing at a rapid rate since 1970 although the rate has declined somewhat since 1990. As of the year 2008, there were 254,780 people working in the city, which is about one-fourth of the region's total employment (Bureau of Economic Analysis). Between 1990 and 2000, employment grew at an average annual rate of 2.3 percent compared to 1.0 percent for the MSA. Since 2000, the rate has declined to 1.1 percent for the city and increased to 1.2 percent for the MSA.

Virginia Beach's economy is highly dependent on the Federal Government, which is the largest single employer in the city as well as in the region. For Virginia Beach most of this employment is concentrated in the four Federal military bases located in the city: Little Creek Amphibious Base, Dam Neck, Oceana Naval Air Station, and Fort Story. As of 2008, there were an estimated 22,368 military and 5,276 Federal civilian jobs in the city, which together make up 11 percent of Virginia Beach's total employment (BEA).

As of 2008, the largest numbers of jobs in the city are in the services sector with 29.5 percent, followed by the trade and government sectors with 14.4 percent and 19.8 percent, respectively (BEA). Employment in these sectors will continue to increase as long as the city's population continues to grow. Other smaller but significant sectors include construction and the finance, insurance, and real estate sectors, which provide 19.0 percent of the city's employment. Both manufacturing and agricultural employment have been declining in relative importance and now make up less than three percent of the total employment.

2.8.4 <u>Income</u>. Income levels for the city's residents are higher than those for the MSA as a whole and slightly higher than those for the state, based on median family and per capita income estimates. Census data show that 2007 median family income was estimated to be $74,358 for Virginia Beach compared to $68,331 for the MSA and $73,192 for the state (U.S. Census Bureau, 2008). The estimated 2007 median household income was $65,776 for Virginia Beach and $57,122 for the MSA (U.S. Census Bureau, 2008). Per capita income for 2008 was $45,022 for Virginia Beach while it was $39,300 for the MSA and $44,075 for the state (BEA). Virginia Beach's per capita income was also above the national average of $40,166 (BEA).

Table 5 provides information on the population (current and forecasted), employment, and income for the City of Virginia Beach and the MSA.

Table 5. DEMOGRAPHIC INFORMATION

	Virginia Beach	MSA
Population		
1990	393,089	1,396,107
2000	425,257	1,569,541
2009 (estimated)	434,412	1,644,008
2020 (projected)	470,288	1,822,160
2030 (projected)	493,095	1,956,013
Employment		
1990	185,304	860,949
2000	232,622	948,105
2008	254,780	1,046,018
Income ($)		
Median family (2000)	53,242	49,186
Median household (2000)	48,705	42,448
Per Capita (2000)	30,661	26,762
Median family (2007)	74,358	68,331
Median household (2007)	65,776	57,122
Per Capita (2008)	45,022	39,300

Sources: U.S. Census, Bureau of Economic Analysis, Weldon Cooper Center for Public Service, and Virginia Employment Commission

2.8.5 Environmental Justice Communities. Data on both the racial composition and income levels of the residents of the study area are necessary to determine if the study area would fit the definition of either a minority or low-income community and thus be subject to the provisions of EO 12989 on Environmental Justice. An analysis of the data for the census tracts which encompass the study area shows that the tracts have a minority population of 18 percent compared to 29 percent for Virginia Beach as a whole (U.S. Census, 2000). Data on the percentage of people living below the poverty line shows the study area with 8.5 percent of the population in that category and 6.5 percent for the city (U.S. Census, 2000). Table 6 shows the specific data for each tract that is partially or totally in the study area. The study area does not meet the criteria for being a minority area since the percentage of minority residents is below 50 percent and is lower than the percentage for the city as a whole. The study area also is not a low income area since the percentage of residents in poverty is low in absolute terms and, while slightly larger than that for the city overall, the relative difference is not considered large enough to be meaningful.

Table 6. CENSUS TRACT ENVIRONMENTAL JUSTICE DATA (2000)

Tract	Total Population	Percent Minority	Percent in Poverty
410.03	3,710	20.2	2.3
420	3,535	5.9	2.7
430.01	8,014	4.2	2.4
430.02	4,086	6.5	2.4
432	1,055	56.3	8.3
442	6,512	41.8	27.0
444.02	6,286	14.7	6.5
446	6,129	3.5	2.3
448.06	5,299	38.4	16.4
Total	44,626	18.0	8.5
Virginia Beach	425,257	28.6	6.5

Source: U.S. Census, 2000

2.9 Cultural Resources

The first inhabitants of the southeastern part of Virginia were the Native Americans, who occupied the Chesapeake area for at least 10,000 years before European settlement. Archaeological evidence from the earliest inhabitants is very sparse, but by the Woodland Period (1200 B.C. to 1607) there were camps and villages with Native Americans raising crops and using the resources from the rivers and Atlantic Ocean. The Indians who occupied the Virginia Beach area up to the end of the 16th century were members of the Chesapeake tribe (McDonald and Laird, 1996). There are accounts of some contact between Spanish explorers and the Chesapeake Indians in the Virginia Beach area in the late 16th century (Frazier Asso., 1992). In 1586, John White and Thomas Herriot from the Roanoke Island colony produced a map showing an Indian village located near the Lynnhaven River (McSherry, 1993). However, in 1609, English colonists went six to seven miles up the Lynnhaven or Elizabeth River and found a few Indian houses but no inhabitants (McDonald and Laird, 1996).

Virginia Beach's recorded history generally begins in 1607 with the landing at Cape Henry of the English settlers who eventually established the first permanent colony at Jamestown. Although the first colonists settled inland away from the coast, by 1635 settlers had started to move into the Hampton Roads area, settling along the Elizabeth, Lynnhaven, and North Landing Rivers and the north-south ridges of arable land. Among the first men to move to this area was Adam Thoroughgood, who, along with others, established a home along the Lynnhaven River. Thoroughgood and others owned land in the area that would later become part of Princess Anne County, the county which would eventually make up the majority of modern day Virginia Beach (Frazier Asso., 1992).

The original town of Virginia Beach began as a small settlement near the Seatack Life Station, which is located near the oceanfront. Toward the end of the 19th century, the town began to grow quickly as hotels and vacation cottages were constructed. By 1906, Virginia Beach had become an incorporated town, and in 1923, it annexed a small part of the county. In 1963, Princess Anne County and the town of Virginia Beach merged to become the City of Virginia Beach with its current boundaries. More information on the prehistory and history of Virginia Beach can be found in Appendix D.

From the beginning of Virginia Beach's settlement, the Lynnhaven River was used by various vessels for local transportation and as an anchorage area until conditions were favorable for leaving the Chesapeake Bay. Some historical accounts attribute the formation of Lynnhaven Inlet to a major storm that occurred shortly after local residents had dug a channel through a sandbar at the mouth of river for their canoes about 1700 (Virginia Canals and Navigations Society, 1998). However, most map and documentary evidence indicates that the Inlet has been open since the early 1600s (McDonald and Laird, 1996). As early as 1703 and as late as 1914, there are reports of shipwrecks or vessels running aground in the area of Lynnhaven Inlet and River or Bay as it was called by some people in earlier centuries. In 1994, the remains of a 19th century shipwreck located in Lynnhaven Inlet in the vicinity of the Federal navigation channel were accidentally discovered during maintenance dredging activities. In 2003, the USACE Norfolk District had an archaeological data recovery survey for the remains of this shipwreck carried out by Tidewater Atlantic Research, Inc. The report for this data recovery is entitled *Archaeological Data Recovery at 44VB239 Lynnhaven Inlet, Virginia* (2004).

Because of the long settlement history of Virginia Beach, there are numerous recorded historical sites within the city. The city's own inventory of historic resources and properties contains over 400 listings. There are also 14 areas designated as historic and cultural districts and 18 properties listed on the National Register of Historic Places. Within the Lynnhaven River Basin, there are also numerous recorded archaeological and historical sites.

An inventory of sites in the Virginia Department of Historic Resources (VDHR) database within a half mile of the potential Lynnhaven River restoration sites resulted in a list of 58 sites, most of which are 20^{th} century houses. A complete listing of these sites can be found in Appendix D. No sites were found within the restoration areas themselves although there are two historic sites that are adjacent to restoration areas. The first of these is the Seashore State Park Historic District, which is next to the Narrows to Rainey Gut area. This district is listed on the National Register of Historic Places (NRHP) and encompasses First Landing State Park. The second site is the Norfolk and Virginia Beach Railroad, which runs in a west to east direction from Norfolk through Virginia Beach to the oceanfront and extends along the southern end of the South Great Neck restoration area. This site has been determined eligible by VDHR staff because of its role in the development of the Virginia Beach oceanfront and in the creation of small settlements along its corridor.

The greatest number of sites (41) was found in the vicinity of the North and South Great Neck areas. All of these sites with the exception of the Norfolk and Virginia Beach Railroad consist of 20^{th} century structures located at least 500 feet away from the potential restoration sites. About half these sites have been determined not eligible for NRHP listing, and no determination has been made for the rest of the sites except for the Norfolk and Virginia Beach railroad.

All three of the sites in the Mill Dam Creek area are located at least 2,300 feet from the restoration site. Two of these sites are archaeological sites, and the other is an 18th century house. None of these sites has had a significance determination made for it.

There are five archaeological sites located within the vicinity of the Narrows to Rainey Gut restoration area, the closest of which is approximately 265 feet from the restoration area. Two of the sites are prehistoric era sites, two are 19th century sites shown on maps only, and one site contains both prehistoric and historic elements. No significance determinations have been done for these sites. The Seashore State Historic District, which is listed on the NRHP, is located adjacent to the potential project area.

There are two historical sites in the vicinity of the Princess Anne High School restoration area. The first, the building which was used as a tuberculosis sanatorium, has not been evaluated for NRHP eligibility; it is located about 800 feet from the restoration site. The second is the Norfolk and Virginia Beach Railroad, which is located about 1,900 feet from the site and was discussed above.

There are three sites located near Fish House Island, all of which have been determined not eligible for listing on the NRHP. These sites consist of a restaurant, house, and a bridge, all of which were built in the 20th century.

No recorded sites were found in the Lynnhaven River itself at or near the proposed locations for the fish reef structures. The closest recorded sites to the proposed locations were an eligible archaeological site on land about 600 feet away from the location of Reef Habitat (RH) 1, an archaeological site about 2,500 feet away from RH 2, and 1920s house about 500 feet away from RH 4. No eligibility determinations have been made for the second two sites.

2.10 Wild and Scenic Rivers

No portion of the Lynnhaven River is considered either a national or state wild and scenic river. However, the entirety of the Lynnhaven River Basin has been designated part of the city's Scenic Waterway system by the City Council of Virginia Beach.

2.11 Hazardous, Toxic, and Radioactive Waste

During the feasibility phase an investigation was completed to determine the potential for hazardous, toxic, and radioactive waste (HTRW) in the project area. A Phase I Environmental Site Assessment (ESA) was performed on the four wetlands restoration/diversification sites proposed for the Lynnhaven River Basin Restoration Study. The ESA was only performed on the wetland project areas and not on the areas proposed for the other restoration measures (scallop restoration, reef habitat construction, and SAV plantings), due to the fact that these sites are subaquatic and the proposed treatments will involve the minimal or no disturbance of the sediment. The conclusion of that investigation is that there is no evidence that HTRW exists in the wetland sites. The complete HTRW analysis is located in the Environmental Appendix.

3.0 PROBLEMS, OPPORTUNITIES, AND OBJECTIVES

3.1 Problems

The environmental decline of the Lynnhaven River has its roots in the agricultural methods used in the area over a century ago. Farming practices such as the clearing and tilling of fields resulted in increased amounts of sediment entering the water column, while inadequate waste management practices accounted for high levels of bacteria such as fecal coliform in the river. As the farms gave way to neighborhoods, the bacteria levels remained high due to the increased runoff from paved surfaces and leaking septic systems. The development of the Basin from a mostly agrarian region to a suburban area with shopping malls, industrial parks, and office buildings, much of which has occurred over the past 40 years, has adversely affected the biological life in and adjacent to the Lynnhaven River in various ways.

3.1.1 Loss of SAV Habitat. SAV habitats contribute to numerous ecological functions, including sediment stabilization, nutrient transformation and cycling, primary production, and forage and nursery habitat for both recreationally and commercially important fish and shellfish. Historically, hundreds to thousands of acres of SAV were present, although populations of eelgrass, the species most prevalent in the region, are known to fluctuate. As the surrounding region became more developed, SAV populations in the Lynnhaven River have declined.

SAV is particularly sensitive to reductions in water clarity, increases in nutrient loads, and substrate changes. In the Lynnhaven River, extensive development of the land caused significant inputs of terrestrial sediments into the river Basin and was the primary cause of SAV decline in the river Basin. Additionally, high TSS levels in the water, along with eutrophication and slowly increasing water temperatures, acted along with a lack of a seed source to inhibit its recovery (Cerco and Moore, 2001).

In 2005, an extensive SAV die off, apparently due to a very hot summer coupled with poor water quality, extirpated the remaining SAV from the Lynnhaven River system except for small, transient patches. Bay-wide, SAV has partially recovered from the 2005 die off, but this has not occurred in the Lynnhaven River. Even though the water quality has improved enough to support SAV, the Lynnhaven system does not have the significant seed sources necessary to re-establish a self sustaining SAV population in the project study area nor have significant SAV restoration activities been initiated. According to the latest estimates, less than 20 acres of SAV remain in the entire Lynnhaven River system and this represents a recovery from near total absence in the past five years.

3.1.2 Loss of Reef Habitat. Benthic surveys done during the study showed that, in general, the Lynnhaven River is far from a pristine system. Habitat diversity is limited and species diversity is considerably lower than reference, undisturbed aquatic habitat. Over time, there has been a loss of reef structure and the diversity of fish and other aquatic life it supports. In this region, oysters formed three-dimensional reefs used by fish, not corals. The loss of this rocky three dimensional reef habitat has also adversely affected oysters and the benefits they provide to water quality from the filtration they carry out. One of the main causes of this loss of reef habitat is the deposition of large amounts of terrestrial sediments over considerable areas of the sandy bottoms formerly found throughout most of the system, particularly in upstream regions of the eastern and western branch and the middle portion of Linkhorn Bay. The soft sediments are generally not as suitable substrate for reef structures as hard, sandy bottom.

3.1.3 Reduced Water Quality. The nature of the drainage from the Lynnhaven watershed has changed as the area developed from a rural, agriculture based community to an urban center, particularly over the last forty years. Increased volume and decreased quality of stormwater runoff, including pollution from streets, parking lots, fertilized lawns, and failing or inadequate septic systems, have collectively degraded water quality. Recently, the City of Virginia Beach, Federal and state organizations, and conservation groups such as Lynnhaven River NOW have taken actions towards improving the water quality within the Lynnhaven River Basin. Four water quality parameters have been recognized by Lynnhaven River NOW as the most significantly elements which must be addressed in order to improve the health of the system. These are low water clarity, high concentrations of the dissolved nutrients nitrogen and phosphorus, high bacterial contamination, and low dissolved oxygen.

3.1.4 Siltation. Excessive siltation is another problem experienced within some areas of the Lynnhaven River Basin. As explained previously, several conditions existed within the system that contributed to this issue, extensive agricultural areas and conversion to urban development, are no longer as prevalent in the Basin. Currently, stormwater runoff moves exposed sediments from disturbed terrestrial areas into the river and unstable shorelines and eroding bank also act as sources of sediment entering the Lynnhaven Basin. At the same time habitats which can trap suspended materials before they enter the water column, including riparian buffers and wetlands, have been lost due to development. All of these circumstances have resulted in the deposit of large quantities of soft silts over sizeable regions of the sandy bottom that would have been suitable areas for SAV and reef habitat thus providing an impediment to the natural recovery of these habitats and their functions in the ecosystem. Today, this sediment is several feet thick in some areas, particularly in the headwater areas and in sheltered coves, where tidal flushing is unable to move it effectively.

The City Virginia Beach has implemented best management practices for new construction, stormwater retention ponds, greenscaping, and encouraging homeowners living along the shoreline to maintain protective hard structures if present and, if not present, maintain a natural marsh shoreline. Street sweeping, buffers, and erosion control at construction sites have been ramped up over recent years. Living shoreline reefs are being placed by local environmental groups (Lynnhaven River NOW) and may also be placed as part of the proposed plan. Several sites are currently being recommended for nearshore placement of reef structures to provide benefits to aquatic life as well as stabilizing the shoreline.

3.1.5 Loss of Tidal Wetlands. Similar to the trend observed in the United States as a whole, wetland loss has been associated with the development of the Virginia Beach area. In 1979, 860 acres of tidal wetlands were reported in the Lynnhaven Basin (Barnard and Dumlele, 1979); however, during the most recent study conducted by VIMS in 2007, only 699.3 acres remained (Berman, 2009). This loss has been primarily linked with the development of the region and the filling of marshes in order to create more dry land for homes, industry, and agriculture. Wetlands have also been lost due to the damming of small creeks and marsh channels to create lakes and waterfront property. The hardening of the shoreline with some form of engineered protection (e.g. bulkhead, riprap) is another cause of tidal marsh lands loss. It is estimated that 24 percent of the shoreline in the Lynnhaven system is currently hardened.

3.1.6 Invasive Wetland Species. Native plant communities within the Lynnhaven River have been replaced by *Phragmites australis*. The impact of this invasive plant may be considered more profound in the Lynnhaven than perhaps in other areas due to the vulnerability and scarcity of the remaining wetlands.

3.1.7 Loss of Bay Scallops. With the extirpation of the bay scallop from the Lynnhaven River Basin in the 1930's, the Basin lost an important member of the filter feeding organism community as well as an important piece of the food chain.

3.2 Opportunities

3.2.1 Submerged Aquatic Vegetation. The loss of SAV has not been due entirely to natural conditions, but rather to conditions that have resulted from a combination of natural conditions and human impacts. SAV is usually able to recover to its former extent from the impacts of hurricanes and other storms. There are exceptions, for example large portions of seaside embayments on the Eastern Shore of Virginia, where SAV was so completely denuded by the dieback during the 1930's that there was no remnant SAV population to serve as a source of seeds and other propagules to recolonize the area. The Eastern Shore is a situation rather similar to what exists in the Lynnhaven River today. Efforts have been initiated within the Eastern Shore embayments to restore SAV via direct seeding of the shallow water habitat and have been very successful (ERDC, 2008 – Restoring Eelgrass From Seed: A Comparison of Planting Methods for Large-Scale Projects, Orth et al., 2006 – Seagrass Recovery in the Delmarva Coastal Bays, USA, ERDC citation, 2006). These successful results provide an example of SAV restoration that could be applied to the Lynnhaven River. Additionally, the Lynnhaven River contains ample restorable habitat for SAV because of its predominantly sandy substrate and shallow depths. Despite the considerable siltation that has occurred during human development of the Basin in the past, enough sandy regions remain to consider the restoration of SAV in the Lynnhaven Basin.

3.2.2 Reef Habitat. Hard structure habitat is of great ecological importance in the estuarine environment. It provides attachment surfaces for sessile (fixed in place) organisms, cover and shelter for many species of fish and other motile invertebrates such as crabs and shrimp, and attachment surfaces for benthic egg masses produced by a wide variety of species ranging from mollusks (whelks) to fish (toadfish) in the Chesapeake Bay. Such habitat in estuaries generally consists of rocky bottom areas and, in many regions, oyster reefs. In the Lynnhaven River, this habitat was historically oyster reefs, which in pre-colonial times were found both sub and inter-tidally throughout portions of the river where salinity levels were high enough to support oyster survival and growth. Today, most of these areas have been either entirely lost (Chipman, 1948; Haven, 1979) or in some cases completely covered with considerable amounts of soft sediments (Dauer, pers. comm.). Extensive bottom surveys conducted in the course of oyster restoration planning (USACE, 2005) discovered two small (< 1 acre) natural oysters reefs near the confluence of Lynnhaven Bay and the Western Branch of the Lynnhaven River. These reefs were quite productive, containing approximately 250 adult oysters/square yard, indicating the subtidal hard substrate can still attract significant populations of oysters and other filter feeders and, in turn, attract a wide variety of fin and shell fish species that utilize reef habitat.

Unlike SAV, artificial reefs do not require a narrow set of environmental parameters in order to function. The main consideration is that the appropriate bottom type be used on which to place them, as excessive subsidence may result if softer bottom types with high percentages of fines are used. For benefits purposes, oysters were considered along with fish and the reefs will be considered dual purpose fish and oyster reefs throughout the study and for benefits modeling.

3.2.3 Bay Scallop Restoration. Bay Scallops are a motile filter feeder, with adult scallops having a filtration rate similar to that of a market sized (3 inch) oyster. Adult scallops of 2.5mm in size have filtration rates as high as 6.75 gallons per hour (Chipman and Hopkins, 1954) during the summer, when water temperatures are at their warmest and the metabolic rate of the scallops is at their annual peak. Their average rate is approximately four gallons per hour. Although the scallop is smaller than the oyster, its metabolic rate is higher due to its mobility and active lifestyle, as adult oysters are completely sessile. Similar to oysters, scallops remove Total Suspended Solids (TSS) and phytoplankton from the water column, retaining the plankton as food and depositing the TSS in their pseudofeces, which is then eliminated and typically becomes incorporated into the sediments. Scallops improve water clarity with their filtration and this improvement provides additional benefits such as allowing for SAV bed expansion, increased benthic diatom diversity and productivity, and improved filter feeding efficiency for other bay filter feeders, as less TSS in the water requires less energy to process and eliminate. Therefore, lower TSS levels would allow for increased feeding efficiency for all filter feeding life in local waters.

Bay Scallops play an important role in the estuarine food web. In addition to providing a link between planktonic and benthic food webs via their filter feeding, scallops serve as a source of food for aquatic predators such as green crabs, rock crabs, mud crabs, blue crabs, sheepshead, cow-nose rays, drum fish, and others (Seitz et al., 2009; Strieb et al., 1995; Pohle et al., 1991). A restored scallop population will then provide for increased secondary production via their own tissue and then throughout the estuarine food web as they serve as a prey item for a wide variety of nekton.

3.2.4 <u>Benthic Habitat Restoration</u>. Many areas located within the Basin with naturally occurring sandy bottom have been found to be completely covered by a layer of fine silty material. The layer of silt smothers the typical benthic community found in shallow, estuarine habitat. The more diverse, native community is then replaced by a very few tolerant species that can inhabit degraded benthic habitat.

Currently, there are no programs in place to remove silt from areas in the Lynnhaven other than in the Federal and city channels. An opportunity exists for the restoration of the benthic community through the removal of the silt layer that is covering the sea floor at sites within the Basin.

3.2.5 <u>Wetland Creation</u>. Presently, while tidal wetlands are regulated by USACE, VDEQ, VMRC, and the local Wetlands Boards, wetlands are still being altered via the permit process. Since about 1980, most major construction projects approved in the Basin, including dredging projects, have required compensatory mitigation to offset tidal wetland losses. However, this approach does not achieve a net gain of wetland acreage and does not address losses that occurred before the permit process was initiated in the 1970's.

The technology exists to construct tidal wetlands with a high degree of certainty and reliability. However, large-scale wetland construction programs or initiatives are not currently being pursued in the Lynnhaven River Basin. Several small-scale wetland restoration projects have been completed and others will likely be constructed in the future as compensatory mitigation for tidal wetlands impacts.

Areas within the Basin have been identified where new salt marsh habitat can be constructed, resulting in an increase in the overall acreage of tidal wetlands located within the Basin. These areas include sites where wetlands did exist and were eventually lost and sites where wetlands have not existed previously. This project element offers a significant environmental opportunity by acting counter to the nationwide trend of wetland acreage loss.

3.2.6 <u>Dam Removal.</u> Large swaths of the Lynnhaven Basin were cut off from tidal influence when small dams were constructed to form artificial lakes. The lakes were built to improve private property values by creating waterfront land. However, these alterations reduced tidal inundation in the areas upstream of the dams, cutting off areas of tidally influenced habitat from the ocean. These areas transitioned into mostly degraded freshwater habitats. Removing these small dams would provide an opportunity to restore many acres of estuarine habitat.

3.2.7 <u>Wetlands Restoration/Diversification.</u> A large percentage of salt marshes within the Lynnhaven River Basin have been colonized by the invasive species, *Phragmites australis*. At many of these sites *P. australis* has entirely replaced the native plant community to become the dominant plant species. There are many opportunities within the Basin to pursue restoration of the native salt marsh, however this process is complicated and often requires years of dedicated effort. Tidal wetland restoration technology is site specific and is dictated by substrate conditions, hydrology, salinity, tidal range, wave and wind action, elevation, and in this case, the presence of invasive vegetation. *P. australis* eradication is a complex, long-term program that should not be undertaken without the continued commitment of the sponsor. An aggressive program to eradicate *P. australis* may include burning, changing elevations in disturbed areas or other soil manipulations, and numerous cyclical applications of herbicides. Monitoring is also imperative because *P. australis* tends to reinvade and control techniques may need to be applied several times or, perhaps, in perpetuity. Benefits to be achieved will be in terms of rehabilitated acreages of wetlands vegetated by diverse native assemblages of emergent wetland plants.

It is also important to note that some areas have been so heavily manipulated and degraded that it may be impossible to eliminate *P. australis* from them or to reestablish the native plant community. At these sites, habitat quality may still be improved through the addition of habitat diversity to the uniformity of a mature *P. australis* bed. Habitat complexity can be increased through the creation of features such as shallow pools, tidal channels, and uplands.

3.3 Objectives

Based on the ecosystem restoration problems, needs, and concerns identified in the study area, a number of specific planning objectives have been established to assist in the development and evaluation of alternative restoration measures. Specifically, the objectives focus on four areas for restoration in the study area: (1) fish/oyster reef habitat, (2) SAV, (3) tidal wetlands, and (4) aquatic species reintroduction. These were quantitatively and qualitatively evaluated to determine specific project objectives and various alternatives to achieve them. Each of the four focus areas either directly or indirectly serves diverse functions, including fish foraging and nursery habitat; shelter and feeding areas for blue crabs and other invertebrates; and feeding, resting, and nesting areas for various species of waterfowl. The following specific objectives have been identified:

1. Increase the diversity, productivity, and sustainability of reef habitat within the Lynnhaven River Basin by constructing 25 - 35 acres of three-dimensional reef habitat by five years after the completion of construction. This acreage reflects the available area for reef habitat and provides varied location of reef habitat in each of the main Bays.

2. Create and maintain between 20 and 100 acres of self-sustaining population of SAVs in the Lynnhaven River System by five years after the completion of construction. These acreages reflect the ecologically viable and reasonably available restoration area. SAV will likely spread to any Suitable Areas in the system which are capable of supporting SAV.

3. Preserve marsh function through increased habitat and species diversity and sustainability by restoring 20 - 25- acres of native marsh five years after the completion of construction.

4. Reduce the acreage of invasive marsh plants by 75% for at least two wetland sites throughout the Basin ten years after the completion of construction.

5. Create a self-sustaining population of Bay Scallops by reintroducing Bay Scallops to the Lynnhaven River Basin where SAV has been successfully established and maintain a Bay Scallop population of 1,000,000 individuals in the system five years after the completion of construction. The population goal is based on work done in sub-estuaries and embayments in other regions, including the Northeast, Southeast and Gulf Coasts, and the nearby lower Eastern Shore, Virginia, where most stocking efforts have aimed for establishing approximately 500,000 animals (Tettlebach and Smith 2009).

3.4 Constraints

Planning constraints are defined as any policy, technical, environmental, economic, social, regional, local, or institutional considerations that act to restrict or otherwise impact the planning process. Typical general constraints include state-of-the-art limitations, time, money, uncertainty of the future, policy, and the inaccuracies inherent in design procedures on which alternative plans are based. A summary of the formulation and evaluation criteria for ecosystem restoration options used in this study is presented in subsequent paragraphs. These criteria involve physical, economic, environmental, and social factors that tend, in varying degrees, to constrain the options and/or ultimate selection of a restoration plan or plans for the Lynnhaven River Watershed. Although all of the formulation and evaluation criteria were considered for the various alternatives, key factors or constraints can be further summarized as follows:

- Adverse impacts to existing fisheries should be avoided;
- Adverse effects to navigation channels, navigational aids, and existing infrastructure must be avoided; and
- Restoration measures cannot be built on private oyster leases or private property.

4.0 FUTURE WITHOUT PROJECT CONDITION

The Lynnhaven River Basin is almost completely built out, leaving little room for future development. Inputs into the system from storm water runoff are not expected to increase from the present volumes. The City of Virginia Beach is currently implementing a widespread stormwater retrofit within the Lynnhaven River Basin. Please see Section 2.3.2 and Section 3.1.4 for a discussion of water quality improvement projects and programs being implemented by the City of Virginia Beach and the success to date of those projects and programs.

4.1 Submerged Aquatic Vegetation

SAV habitat may experience a slight increase due to ongoing small-scale restoration and transplantation efforts initiated by the City of Virginia Beach and other resource organizations such as Chesapeake Bay Foundation and VIMS. SAV restoration is also identified as an element of the Lynnhaven River Oyster Heritage Strategic Plan. However, these small scale efforts, though commendable, will not develop a sufficiently large population of SAV to make a resilient population in the Lynnhaven. Therefore, future conditions would likely result in some minimal increased acreage of SAV habitat as well as some associated water quality benefits, but a comprehensive approach to ecosystem restoration of the Lynnhaven River system would not occur. It is unlikely that small-scale efforts such as this local plan would be able to create a resilient population which could rebound from discreet events (such as hurricanes, northeasters, etc.) in the Basin. Additionally, the Chesapeake Bay Program Tier I goal for restored SAV acreage will not be met in the foreseeable future.

4.2 Reef Habitat

Hard substrate with significant bottom relief will remain at critically low levels throughout the Lynnhaven river system. The benthic community (particularly oysters) that relies on this habitat type will remain at low levels, with the concomitant low level of ecological services it provides. Fish species that frequent or require hard reef habitat will also remain at low to absent levels within the Lynnhaven River system. One final ecological service such habitat provides is the stabilization of bottom sediments from resuspension during tidal action and storm events. Without the presence of the reefs to physically increase water clarity, such resuspension will continue unabated.

4.3 Bay Scallops

Scallops have not been present in this area or in other former habitat along Virginia's lower Eastern Shore since at least the early 1930's when scallops were extirpated as a result of a massive SAV die off at that time. There is no scallop population near enough to recruit to the area in any numbers. Left alone, there is no real chance for scallops to ever recolonize the Lynnhaven River or any other nearby habitat. The study area will lack this important filter feeding mollusk without intervention. SAV and scallops are closely linked, so in order to restore scallops, SAV must also be restored to provide its critical habitat.

4.4 Water Quality

Water quality trends in the Lynnhaven have shown an increase in salinity, likely due to sea level rise, which allows greater amounts of saltier Atlantic Ocean and lower bay waters to enter the Lynnhaven River. Levels of TSS, nitrogen compounds, and chlorophyll A have slowly declined and water clarity has increased. These improvements are due to restoration measures initiated by the City of Virginia Beach. The city has placed 11,362 homes which had individual septic systems onto the city sewer system, prohibited dumping of boat waste into the Lynnhaven River, implemented greenscaping to lessen runoff, and implemented other measures to improve water quality. Efforts by Lynnhaven River Now have also added to water quality improvement by implementing citizen programs that have resulted in less yard and pet waste entering the river. In addition to the projects and programs priorly discussed, the City is also proposing new techniques for nutrient removal such as harvesting phragmites (invasive marsh grass).

In the event that the proposed project is not implemented, water quality will most likely continue to improve. Although the project was not formulated for water quality improvements, the project features will enhance water quality, adding to the efforts currently underway by local authorities. Hard reef substrate and SAV will likely remain at low levels, wetlands proposed for restoration will remain in a degraded state, and without significant SAV recovery, scallops will be unable to recolonize the Lynnhaven River system.

4.5 Tidal Wetlands

While tidal wetlands are regulated by USACE, VDEQ, VMRC, and the local wetlands boards, wetlands are still being altered via permitted human activities. Although no large-scale wetland restoration programs or initiatives are currently being pursued in the Lynnhaven, several small-scale wetland restoration projects have been completed and others will likely be constructed in the future as compensatory mitigation for tidal wetlands impacts. However, this approach does not achieve a net gain of wetland acreage and does not address losses that occurred before the permit process was initiated in the 1970's. The expected future condition (Without Project Alternative) is a continuation of the present conditions, i.e. continued scarcity of pristine, high quality wetland habitat leading to continued degradation and decline of the environmental quality of the Lynnhaven River and all those living resources dependent upon the water quality and habitat benefits that tidal wetlands provide.

Currently, many salt marshes located within the Lynnhaven Basin are dominated by common reed, *P. australis,* which is excluding native salt marsh plant species. Common reed is extremely difficult to eradicate. Unless a wide-scale management program is initiated, it is expected that this invasive plant will continue to dominate sites where it has become established. It is also expected that the acreage of marsh dominated by *P. australis* will increase in the Lynnhaven River Basin in the future. Common reed has numerous competitive advantages over native grass species, including a longer growing season and the ability to alter its physical surroundings to meet the species' optimal growing conditions, which allow it to spread quickly, especially in disturbed sites, and outcompete native marsh plants.

5.0 PLAN FORMULATION

5.1 Formulation and Evaluation Criteria

The purpose of this section of the report is to provide the pertinent technical, economic, environmental, social, and institutional criteria used in the formulation process. The following specific formulation and evaluation criteria have been identified for this study.

5.1.1 Technical Criteria. The plan selected should be consistent with local, regional, and state goals for water resources development;

• Plans must represent sound, safe, and acceptable engineering solutions;
• Plans must comply with USACE regulations;
• Plans must be realistic and reflect state-of-the-art measures and analysis techniques;
• Restoration plans should be conceived in a system context, considering aquatic, wetland, and terrestrial complexes as appropriate;

• Consideration should be given to the interconnectedness and dynamics of natural systems along with human activities, which may influence the results of restoration measures; and

• The significance of restoration outputs should be recognized in terms of institutional, public, and technical importance.

5.1.2 Economic Criteria. Plans for restoring ecological resources are based on both monetary and nonmonetary benefits (base year is 2014 and the Federal discount rate is 4.125%); and

• Cost-effective analysis must show that an alternative plan's output cannot be produced more cost effectively by another alternative.

• Incremental analysis must show that a cost-effective alternative plan's output cannot be produced at a lower incremental cost per unit of output.

5.1.3 Social Criteria. Consideration should be given to public health, safety, and social well-being, including possibly loss of life;

• Plans should minimize the displacement of people, businesses, and the livelihood of residents in the project area;

• Plans should minimize the disruption of normal, anticipated local, and regional growth and effects on local community patterns; and

• Plans should preserve, and where practical, enhance the social, cultural, educational, aesthetic, and historical values of the study area.

5.1.4 Environmental Criteria. Plans cannot have an unreasonably negative impact on environmental resources;

• National Environmental Policy Act documentation must be fully coordinated;

• Water quality standards must be maintained during construction activities in accordance with water quality certification requirements;

• Plans should avoid the destruction or disruption of natural and manmade resources, aesthetic and cultural values, community cohesion, and the availability of public facilities and services;

• Ecosystem restoration plans should be designed to avoid the need for fish and wildlife mitigation;
• Ecosystem restoration plans should be designed to be self-sustaining. If maintenance is necessary, it should be minimal; and
• Plan will be developed in a manner that is consistent with the USACE' Environmental Operating Principles (EOP).

5.1.5 <u>Institutional Criteria</u>. Plans must be consistent with existing Federal, state, and local laws.

5.2 Plan Formulation Process

The plan formulation process is designed to identify plans that are publicly acceptable, implementable, and feasible from economic, environmental, engineering, and social standpoints. It requires the systematic preparation and evaluation of alternative solutions for addressing identified problems, needs, and opportunities under the objectives of NER, consistent with protecting the Nation's environment. Alternative plans are formulated to identify specific ways to achieve the planning objectives so as to solve the identified problems and realize the identified opportunities. Each alternative plan is formulated in consideration of four criteria: (1) completeness, (2) efficiency, (3) effectiveness, and (4) acceptability. Completeness is the extent to which the alternative plans provide and account for all necessary investments or other actions to ensure the realization of the planning objectives, including actions by other Federal and non-Federal entities. Efficiency is the extent to which an alternative plan is the most cost-effective means of achieving the objectives. Effectiveness is the extent to which the alternatives plans contribute to achieve the planning objectives. Acceptability is the extent to which the alternative plans are acceptable in terms of applicable laws, regulations, and public policies.

The plan formulation process requires six essential steps as follows.
• Step 1: Identifying problems and opportunities;
• Step 2: Inventorying and forecasting conditions;

- Step 3: Formulating alternative plans;
- Step 4: Evaluating alternative plans;
- Step 5: Comparing alternative plans; and
- Step 6: Selecting an Ecosystem Restoration Plan.

5.3 Identification of Management Measures

Ecosystem restoration management measures are identified and evaluated individually on the basis of their suitability, applicability, and merit in meeting the planning objectives and constraints for the study. Without undertaking an in-depth analysis, the goal of this step is to screen out those measures that obviously do not fulfill the ecosystem restoration needs of the study or are inappropriate because of other factors, such as prohibitively high costs. Judgments are made about each measure based on knowledge gained from researching past reports and the professional expertise of the study team members and other District personnel. For this study, measures formulated include tidal wetland habitat creation/restoration, planting of SAV beds in optimal locations, placement of reef habitat in optimal locations, removal of dams blocking off areas previously connected to the tidal estuarine environment, restoration of Bay Scallops, removal of accumulated silts in choked areas to create improved subaqueous habitat for oysters and fish, and various nonstructural measures. All measures except for dam removal would improve degraded water quality parameters, including turbidity, TSS, and dissolved nutrient levels, leading to improvements to aquatic habitat in the Lynnhaven System.

5.3.1 Submerged Aquatic Vegetation. This restoration involves the seeding of SAV at sites have been identified within Broad Bay and the Lynnhaven Bay mainstem. The restoration of SAV would represent a significant increase in the river Basin in the amount of blue crab habitat and potential habitat for the reintroduction of the bay scallop. This will meet the objective to restore a self-sustaining acreage of SAV in the Lynnhaven River System within five years of the project's completion. Historic extent of SAV in the Lynnhaven was approximately 175 acres, but given the loss of viable areas for SAV establishment, an appropriate range of SAV under existing conditions would be anticipated to be approximately half of that. Once SAV is established, VIMS studies on the lower eastern shore of Virginia have shown that, it will naturally spread to any remaining suitable areas in the system . The SAV establishment will be necessary for the Bay Scallop restoration but seeding of the Scallop will be necessary to develop that population.

5.3.2 Reef Habitat. This restoration activity involves constructing large, subtidal concrete and/or other material dual purpose fish/oyster reefs that add significant bottom relief. Such structures provide food, shelter, and places for many benthic life forms to reproduce. A wide variety of fish species utilize such rocky habitat, and a number of them are rare when it is not present. Many sessile marine invertebrates require hard substrate to attach to, and without it they cannot survive. Many of these invertebrates are filter feeders and their loss from the benthic community has decreased water quality and also the ability of the river to naturally filter and utilize phytoplankton and organic nutrients.

This measure will meet the objective to increase the productivity, diversity, and sustainability of the reef habitat in the Lynnhaven River Basin by increasing the amount of reef habitat which will promote oyster colonization and provide habitat to support a self sustaining reef fish community. Examples of hard reef structures are pictured below in Figures 6-8.

Figure 6. POTENTIAL HARD REEF STRUCTURE

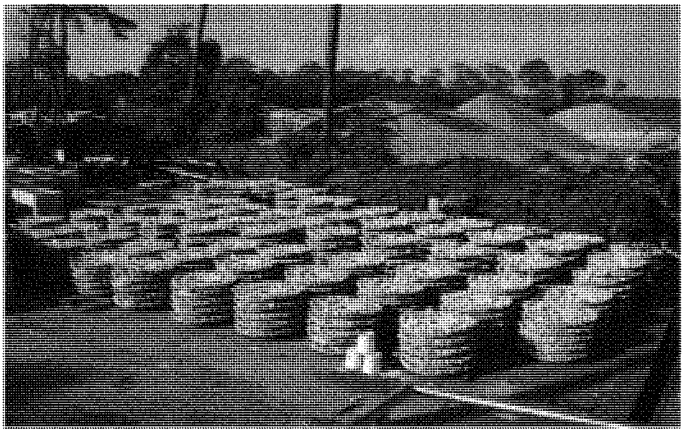
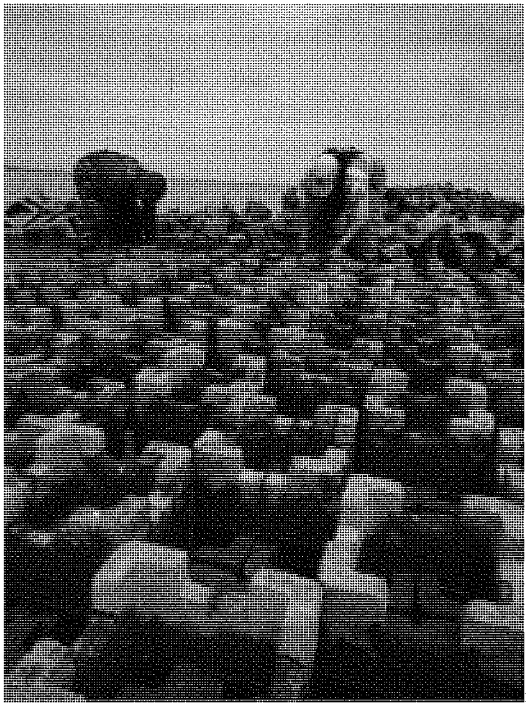


Figure 7. POTENTIAL HARD REEF STRUCTURE

Figure 8. POTENTIAL HARD REEF STRUCTURE



5.3.3 Bay Scallop Restoration. This restoration activity would restore Bay Scallops in areas where SAV has been restored. The bay scallop has not been seen in the Lynnhaven River Basin since at least the 1930's. This filter feeder once provided valuable services to the ecosystem within the Basin. Without a reintroduction of the species, it is unlikely that the scallop will naturally recolonize the Lynnhaven System and reestablish the role it plays in the community because there is no source population located in the vicinity of the river Basin. This will meet the objectives of reestablishing a self sustaining bay scallop population of one million individuals within five years.

SAV beds are the primary habitat for Bay Scallops and the successful reintroduction of Bay Scallops to the Lynnhaven River is highly dependent on the establishment of robust seagrass beds within the project area. Once the conditions are appropriate for SAV restoration, they are also appropriate for Bay Scallop restoration. Implementation of the bay scallop measure must be considered in relationship to implementation of the SAV restoration measure. Scallop restoration will not be initiated until SAV beds are established successfully.

The District has worked with researchers at VIMS to develop a robust implementation and AM plan (see Section 9.5). Scallop restoration is the element of the plan with the greatest risk and complexity. It will require a high degree of coordination with scientists familiar with scallops in order to implement successfully. Upon successful restoration of SAV, field trials of scallops will be initiated, and if these are successful, stepwise implementation of the scallops will be implemented. The AM plan will outline this process, including success metrics and decision points.

5.3.4 <u>Benthic Habitat Restoration</u>. This measure would consist of dredging sediment down to the natural contours to expose "good bottom" for recolonization by benthic organisms. This will promote conditions that support oyster colonization, which is a key component of other restoration initiatives. Several sites were considered for the restoration of benthic habitat. There were two sites presented by the public, Dick's Cove and Thoroughgood Cove, in addition to the sites identified by the project delivery team.

5.3.5 <u>Wetland Creation</u>. Restoring the footprint of lost tidal marsh islands and lost shoreline marshes offers the opportunity to create wetlands. Dredged material could be used to reestablish the original acreage of island or shoreline marshes. The newly constructed area would then be vegetated with native plant species. The creation of tidal marsh will provide habitat for fish and wildlife and support the Chesapeake Bay ecosystem.

5.3.6 <u>Dam Removal</u>. The removal of the small dams would return significant amounts of the river Basin to a tidal estuary environment. As described in the previous section, the restoration of tidal marsh would provide habitat for marine and estuarine fish and wildlife, support the food web of the Chesapeake Bay ecosystem, and improve water quality in the Lynnhaven System.

5.3.7 Wetland Restoration/Diversification. The function of wetland sites that have been compromised due to the presence of *P. australis* can be restored through eradication of the invasive species and reintroduction of the native marsh community species. *P. australis* eradication is a complex, long-term process that should not be undertaken without the continued commitment of the sponsor. An aggressive program to eradicate *P. australis* may include burning, changing elevations in disturbed areas or other soil manipulations, and numerous cyclical applications of herbicides. This would meet the objective of reducing the acreage of invasive marsh plants in the Lynnhaven River system.

At sites where the replacement of *P. australis* with the native marsh community would not be successful (e.g. sites removed from tidal inundation) another method of restoration may be investigated. This method involves increasing habitat diversity through physical alteration of the site. This would meet the objective of preserving marsh function through increasing habitat diversity.

5.4 Identification and Screening of Sites for Each Measure

5.4.1 Submerged Aquatic Vegetation. Drawing from the experience of recent restoration successes, a range of SAV restoration opportunities, employing the newer direct seeding methods, was considered for this project. Prior SAV restoration efforts in the Chesapeake Bay have involved transplanting adult plants into relatively small areas (measures in square feet). These efforts, including some that have occurred in the Lynnhaven River Basin, are extremely labor intensive and have had mixed results. More recent SAV restoration activities in the region have utilized a different strategy. These efforts have employed seeding SAV and have shown promise in the Chesapeake Bay. Because direct seeding is less expensive and is not as labor intensive as the placement of adult plants, larger areas of ocean bottom, typically measured in acres, can be restored (Orth et al 2006, Orth 2012).

A two part process was used to identify all sites within the Lynnhaven Basin that have the potential of supporting SAV beds. First, restoration sites were narrowed to include only areas within the river Basin where SAV beds have existed in the past. Using aerial surveys from 1971, the Chesapeake Bay Program has determined that approximately 175 acres of SAV once existed in the river Basin. Because conditions within the Lynnhaven Basin have changed since the 1970's, a second selection criterion was analyzed. SAV requires specific sediment condition in order to thrive. The historical range of SAV within the Lynnhaven River was compared to information gathered during a recent sediment survey. Those sites that fell within the documented range of SAV and consisted primarily of sand (≥75% sand), with low organic content (5% or less is ideal) (Koch 2001, USEPA 2000) were considered for SAV restoration. Twelve sites, totaling approximately 94 acres, were identified throughout the Lynnhaven River Basin that matched the two criteria. Nine of those sites were located within the Lynnhaven Bay mainstem area, equaling 52 acres. The remaining three sites, with a combined area of approximately 42 acres, were located in the Broad Bay/Linkhorn Bay complex. These sites represent the area throughout the Lynnhaven River that possessed the characteristic that will support successful SAV restoration and were identified as "Suitable Areas" throughout the planning formulation process.

Although 94 acres of the Lynnhaven River have conditions that would support SAV, planting that entire area may not be necessary to reestablish a vibrant SAV community. Recent studies in the lower Chesapeake Bay have produced SAV beds significantly larger than the area that was initially seeded. Once established, mature SAV plants can spread, using seeds and propagules, into surrounding areas. For example, Cobb Bay (large exposed bay on the oceanside of the eastern shore of Virginia with very high salinity) was seeded three times over the last ten years. Only 30 acres were actually seeded, yet in 2011, approximately 865 acres of eelgrass were present in the Cobb Bay (Orth et al. 2006, Orth 2012) . Cobb Bay is the closest location to the Lynnhaven where SAV restoration has been successful.

Using the experience of these recent restoration successes, these 94 acres of the Lynnhaven River, which have conditions that would support SAV sites, were narrowed down to sites that would not only support self-supporting SAV population, but also have the characteristics that would allow distribution of the plants into Suitable Areas of the river. The historical records were again consulted. The last "die-off" of SAV in the Lynnhaven River occurred in 2005. This event caused the destruction of all significant SAV beds within the system. Prior to the "die-off", three large, self-sustaining beds, totaling 22 acres, existed in the Lynnhaven system. These sites included one location in the Lynnhaven Bay mainstem, with an area of approximately six acres and two sites in Broad Bay/Linkhorn Complex with an approximate area of 16 acres. These sites were then analyzed for water currents, tides and other hydrodynamic qualities. It was determined that the Broad Bay sites were especially critical to SAV restoration in the Lynnhaven Basin. Due to the local hydrodynamics, seeds produced in these areas would be circulated throughout Broad Bay/Linkhorn Complex and to beds located elsewhere in the Lynnhaven River Basin. These three sites were labeled "Key Areas" in the formulation process, while "Suitable Areas" was used to signify both the Key Areas and the remaining possible SAV restoration areas.

Six different restoration plans or "scales", representing a range of acreages, were used in plan formulation. Each plan consists of two elements, a restoration level and restoration sites. The two restoration levels are identified as Key Areas and Suitable Areas as described in the previous paragraphs. Site locations were divided into two regions within the Lynnhaven system (1) The Lynnhaven Bay Mainstem and (2) The Broad Bay/Linkhorn Bay complex. The range of options fell between 94 and 16 acres of restoration. The largest plan, 94 acres, included seeding all Suitable Areas in both the Lynnhaven Bay mainstem and the Broad Bay/Linkhorn Bay complex. While the smallest option involved seeding 16 acres, the Key Area sites within the Broad Bay/Linkhorn Bay complex only. The plan that involved planting only the Key Area site that existed in the Mainstem were not brought forward for consideration, because the hydrodynamic conditions at that site would not supply seeds throughout the Lynnhaven system. The six different scales of SAV restoration measure were developed are listed below.

- 94 acres - The Suitable Areas in both the Lynnhaven Bay mainstem and the Broad Bay/Linkhorn Bay complex;
- 68 acres - The Suitable Areas in the Lynnhaven Bay mainstem and the Key Areas in the Broad Bay/Linkhorn Bay;
- 48 acres - The Key Areas in the Lynnhaven Bay mainstem and the Suitable Areas in the Broad Bay/Linkhorn Bay;
- 42 acres - The Suitable Areas in the Broad Bay/Linkhorn Bay complex;
- 22 acres - The Key Areas in both the Lynnhaven Bay mainstem and the Broad Bay/Linkhorn Bay complex; and
- 16 acres - The Key Areas in the Broad Bay/Linkhorn Bay complex.

5.4.2 Reef Habitat. Potential reef habitat restoration sites were identified by first locating river bottom that was available to be developed by USACE. The bottom of the Lynnhaven River is extensively leased to private individuals of oyster harvesting. Sites included in the leasing program would not be available for restoration. Restoration areas in the Lynnhaven River are limited because sites with the best conditions for the placement of hard reef structures are leased to private citizens.

Sediment type was also a critical factor in the development of restoration sites. Sandy, firm substrates were preferred over sites with silty, soft substrates. Due to the weight of the hard reef structures, the structures would sink into fine sediments if placed directly onto the river bottom. Sites with soft sediment or uneven sediment would require additional construction in order to eliminate subsidence.

Other factors that influenced placement of reef structures such as oxygen levels, salinity, and water depth are important, but due to the well-mixed nature of the waters in regions where reef structures are considered, these parameters play a much lesser role when compared to bottom type. As a result, scoping for the placement of reef structure depended primarily on bottom type.

There are nine sites identified for restoration of essential fish habitat within the Lynnhaven River. Four sites, totaling approximately 10.5 acres, are located in the Lynnhaven Bay mainstem. The restoration measure for these sites would involve the placement of low relief hard reef structures that are approximately two feet in height. The final five sites are in the Broad Bay/Linkhorn Bay complex and include the construction of approximately 21 acres of potential fish reefs. High relief hard reef structures, up to six feet in height, were considered for these sites. In total, 20.69 acres with sandy substrate and 10.73 acres, located in the Broad Bay/Linkhorn complex, with soft sediment were considered for the restoration of reef habitat.

In total, five reef habitat measures were developed. Areas with soft sediments on the bottom were analyzed separately from areas with "normal" – i.e. sandy bottom substrate. These measures being:

- 31 acres - All of the Lynnhaven Bay mainstem and Broad Bay/Linkhorn complex sites, both normal and soft bottoms;
- 21 acres - All of the Lynnhaven Bay mainstem sites, but only the normal bottom sites in the Broad Bay/Linkhorn complex;
- 21 acres - Only the Broad Bay/Linkhorn complex sites, both normal and soft bottoms;
- 11 acres - Only the Lynnhaven Bay mainstem sites; and
- 10 acres - Only the sandy bottom sites in the Broad Bay/Linkhorn complex.

5.4.3 Bay Scallop Restoration. Establishing a self-sustaining scallop population is directly related to the success of SAV restoration. Although scallops can live on other substrates (Marshall 1947, Chintata et al. 2005), healthy SAV beds are required to maintain a viable population. Therefore, the same sites identified in Section 5.4.1 for SAV restoration were analyzed for bay scallop restoration, since these sites will be actively seeded. Additionally, the health and density of the SAV beds in these areas will be assessed before bay scallop restoration will be attempted. VIMS, which has been the lead academic institution in the lower Chesapeake Bay with respect to SAV research, monitoring, and restoration, identifies the highest quality SAV beds as covering 70 percent of a given acre of ocean bottom with vegetation. This percent coverage is defined as a "dense" bed according to annual monitoring reports (Orth et al. 1978-2010). Although 70 percent is the optimal goal representing high quality reefs, a lesser density, 50% is reasonably expected to represent a minimum for success. Therefore, the commencement of scallop reintroduction will be dependent on the success of SAV restoration measures of the previous year. The Key Areas acreages of SAV beds at each site as described in Section 5.4.1 must attain a minimum density of 50 percent coverage before scallop restoration efforts would be attempted. If this condition is not met, then additional time will be given before scallop reintroduction is attempted.

The ultimate restoration goal for Lynnhaven River Basin is to establish a population of 1 million animals. This goal was established using experiences gained from other restoration efforts along the Atlantic shoreline and the unique characteristics of the Lynnhaven system. Based on work done in sub-estuaries and embayments in other regions, including the Northeast, Southeast and Gulf Coasts, and the nearby lower Eastern Shore, Virginia, most stocking efforts have aimed for establishing approximately 500,000 animals (Tettlebach and Smith 2009). The larger number selected for the Lynnhaven River effort was due to several reasons. First, there is no data on the population size that has existed in the region. Scallops were extirpated from the Chesapeake Bay region in 1930 due to an extensive SAV die-off, which resulted in recruitment failure of scallops for several years. Due to the short life cycle of scallops, this time period was sufficient to render the local population extinct. While it can be assumed populations in the local region were similar to those in other regions, it is not certain and it was determined that risk would be better managed if a larger population was established. Another reason for choosing a larger restoration goal is that the population in the Lynnhaven River must be completely self-sustaining. Scallop populations in many regions experience limited recruitment from other areas and the occasional influx of larvae can help sustain a population or even allow for the reintroduction of the mollusk species where a population has been lost. Due to annual weather conditions and lack of other local scallop populations, there is no potential for recruitment of scallop larvae from other areas. Finally, the level of predation within the

Lynnhaven is another uncertainty that encouraged a higher goal population. The potential for high levels of predation, from both wildlife and due to poaching, exists in the Lynnhaven River and a larger scallop population will reduce the risk of failure caused by over predation.

To attain the restoration goal of 1 million Bay Scallops inhabiting the Lynnhaven River, ten different restoration plans were evaluated. These plans are listed in Table 7. Each plan consists of two elements, a restoration level and restoration sites. Bay scallop restoration is directly related to the success of SAV restoration; therefore the same levels were considered in both restoration efforts. These two levels of restored acreage are identified as Key Areas and Suitable Areas. A full description of how these two levels were defined is included in Section 5.4.1. The Lynnhaven system was divided into two sub-systems: (1) The Lynnhaven Bay Mainstem and (2) The Broad Bay/Linkhorn Bay complex. The Key Areas in the Broad Bay/Linkhorn Bay complex have an area of 16 acres, while the Key Areas in the Lynnhaven Bay Mainstem have a total area of 6 acres. The area of the Suitable Areas in the Broad Bay/Linkhorn Bay complex and the Lynnhaven Bay Mainstem are 42 acres and 52 acres respectively. The ten scallop restoration plans range in size from 94 acres (Plan 1) to 16 acres (Plans 9 and 10).

SAV does not require scallops, but scallops rely on SAV to survive in sufficient numbers to provide a self-sustaining population. Due to the lack of SAV dependence on scallops, SAV restoration was considered without scallop restoration. However, the only scallop restoration plans that were considered included equal or great amounts of associated SAV restoration. For example, Plan 1 involved equal amounts of scallop and SAV restoration in both Broad Bay/Linkhorn Bay complex and the Lynnhaven Bay Mainstem. Plan 5, however, consisted of a larger area (Suitable Areas) of SAV seeding and a smaller area (Key Areas) of Bay Scallops restoration. Since scallops do not fix themselves to hard substrates and can therefore move from site to site, scallops will spread out of the smaller restoration area into the larger, surrounding SAV bed.

Table 7. THE TEN SCALLOP REINTRODUCTION MEASURES ANALYZED IN RELATIONSHIP TO THE POTENTIAL SAV RESTORATION MEASURES

Plan	Lynnhaven Bay Mainstem		Broad Bay/Linkhorn Bay complex		Total Scallop Restoration (acres)*
	Scallop option	SAV option	Scallop option	SAV option	
1	Suitable Areas (52 acres)	Suitable Areas (52 acres)	Suitable Areas (42 acres)	Suitable Areas (42 acres)	94
2	Key Areas (6 acres)	Key Areas (6 acres)	Key Areas (16 acres)	Key Areas (16 acres)	22
3	Suitable Areas (52 acres)	Suitable Areas (52 acres)	Key Areas (16 acres)	Key Areas (16 acres)	68
4	Key Areas (6 acres)	Key Areas (6 acres)	Suitable Areas (42 acres)	Suitable Areas (42 acres)	48
5	Key Areas (6 acres)	Suitable Areas (52 acres)	Key Areas (16 acres)	Suitable Areas (42 acres)	22
6	Key Areas (6 acres)	Key Areas (6 acres)	Key Areas (16 acres)	Suitable Areas (42 acres)	22
7	Key Areas (6 acres)	Suitable Areas (52 acres)	Key Areas (16 acres)	Key Areas (16 acres)	22
8	No restoration (0 acres)	No restoration (0 acres)	Suitable Areas (42 acres)	Suitable Areas (42 acres)	42
9	No restoration (0 acres)	No restoration (0 acres)	Key Areas (16 acres)	Key Areas (16 acres)	16
10	No restoration (0 acres)	No restoration (0 acres)	Key Areas (16 acres)	Suitable Areas (42 acres)	16

*Acreages in this column only include bay scallop restoration and not area of SAV restoration.

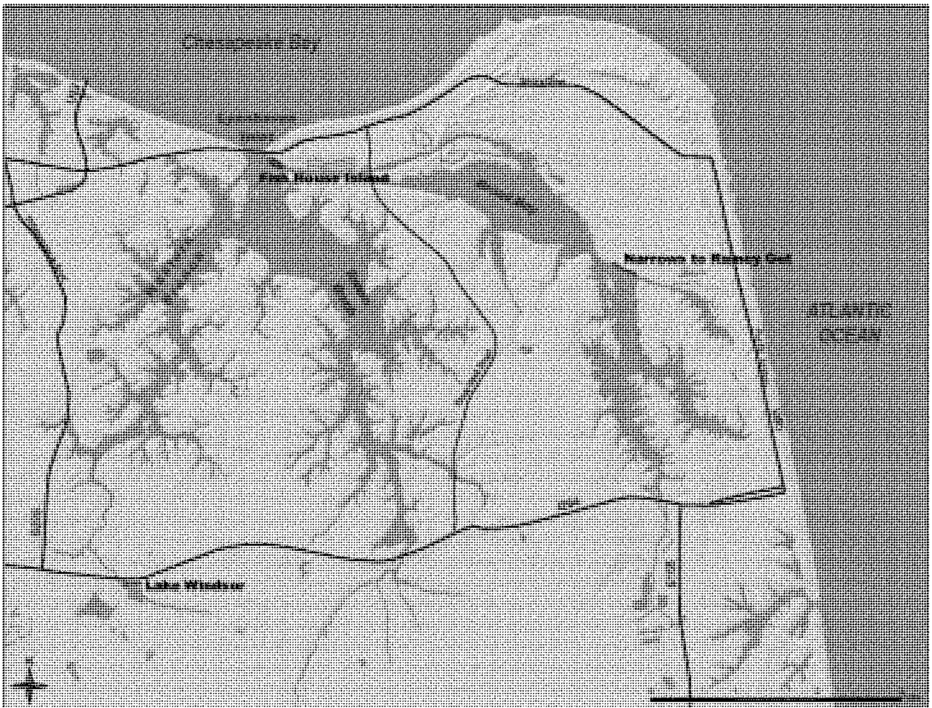
5.4.4 Benthic Habitat Restoration. Many sites were identified for the restoration of benthic habitat; however, maintenance dredging would be required to sustain the restored sites. As a result, either the environmental benefits achieved through the restoration would not be sustained over the life of the project, or the project would have to commit to a maintenance dredging program. Maintenance dredging would be needed to maintain the restored condition due to the likely re-deposition of fine sediments in sheltered waters. Until the majority of terrestrial-derived fine sediments are removed from the system, attempting to restore small areas in sheltered waters is unlikely to succeed without continued maintenance similar to what is done for a navigational channel. For an ecosystem restoration project, such a large maintenance cost makes it less viable an option. Given the unsustainable nature of this measure, it was not carried forward for further evaluation.

5.4.5 Wetland Creation. Three areas have been identified by the sponsor and resource agencies for wetland creation. The sites indentified are as follows: The Narrows to Rainey Gut, Lake Windsor, and Fish House Island. The Narrows to Rainy Gut and Lake Windsor sites do not have any constructability problems associated with them. These sites were carried forward.

Only one potential site for Tidal Marsh Island creation was identified. Fish House Island, located just inside the mouth of the Lynnhaven Inlet, is an example of an island within the Lynnhaven River Basin that has lost significant area and was determined to be a potential site for marsh restoration. Historical aerial photography shows that Fish House Island was approximately ten acres in size in the 1930's. Today, it is approximately 1.25 acres.

Some risk is associated with the restoration of Fish House Island. Erosion is occurring on the island due to significant currents experienced at high and low tides. The restoration of the island will not eliminate these currents and could increase the velocity of the currents due to a reduced cross section outside of the main channels. This could also pose additional risk post construction. Even with the associated risks, this measure represents an opportunity to restore significant amounts of lost wetlands in the Lynnhaven Basin, so this site was carried forward. Three different options were evaluated. These include the "small island" option that included three acres of restoration, the "medium island" option that would result in five acres of marsh and finally the "large island" option, which included eight acres of restoration. The wetlands sites described above are shown in Figure 9.

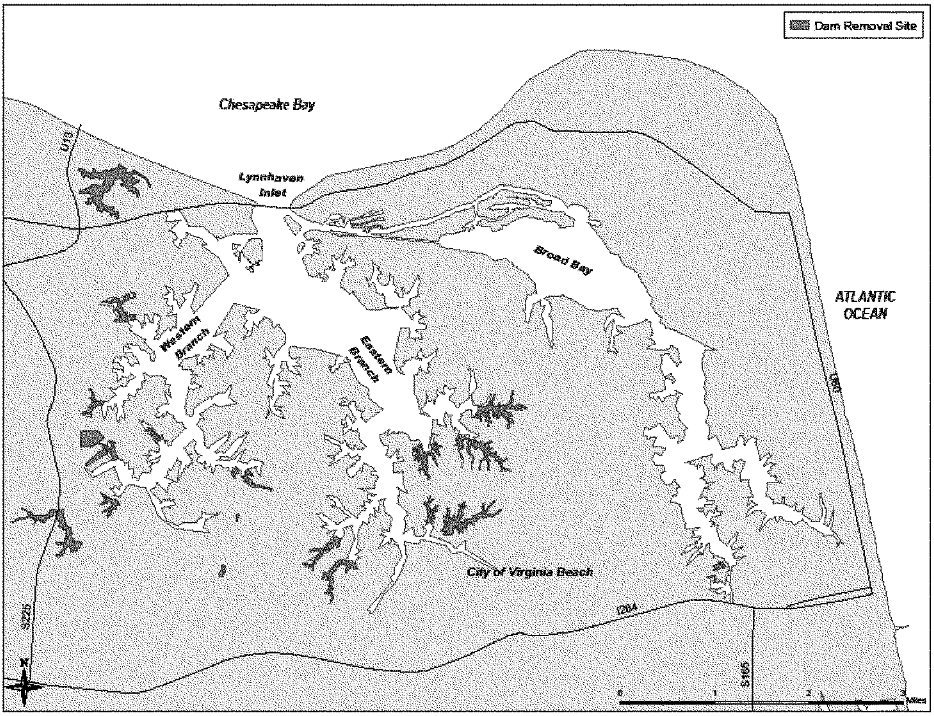
Figure 9. WETLAND CREATION SITES IN THE LYNNHAVEN RIVER BASIN



5.4.6 Dam Removal. There are 22 lakes in the Lynnhaven River Basin. Many of these were a part of the tidal estuary before being dammed. Some of the lakes have been in place for more than a century, while some were constructed in the 1970's. All of the lakes are privately owned. All but one of the dams are privately owned. Two lakes identified in the Lynnhaven Basin were former borrow pits and thus never connected to the tidal estuary; they were removed from further consideration.

During the summer of 2009, three public meetings were held with approximately 600 people in total attendance. The possible removal of the dams was introduced at these meetings and public comments were solicited. Public opinion regarding such removal was overwhelmingly negative. The USACE was not able to obtain permission from all required property owners granting access to their lake to gather further information. This made it impossible to investigate the effects of dam removal on the adjacent shorelines, determine potential shoreline changes, or evaluate the effects on the system of removing a water body that had in essence become an unplanned Best Management Practice. This measure was not carried forward for further evaluation. The dams in the Basin are shown in Figure 10.

Figure 10. DAMS WITHIN THE LYNNHAVEN RIVER BASIN

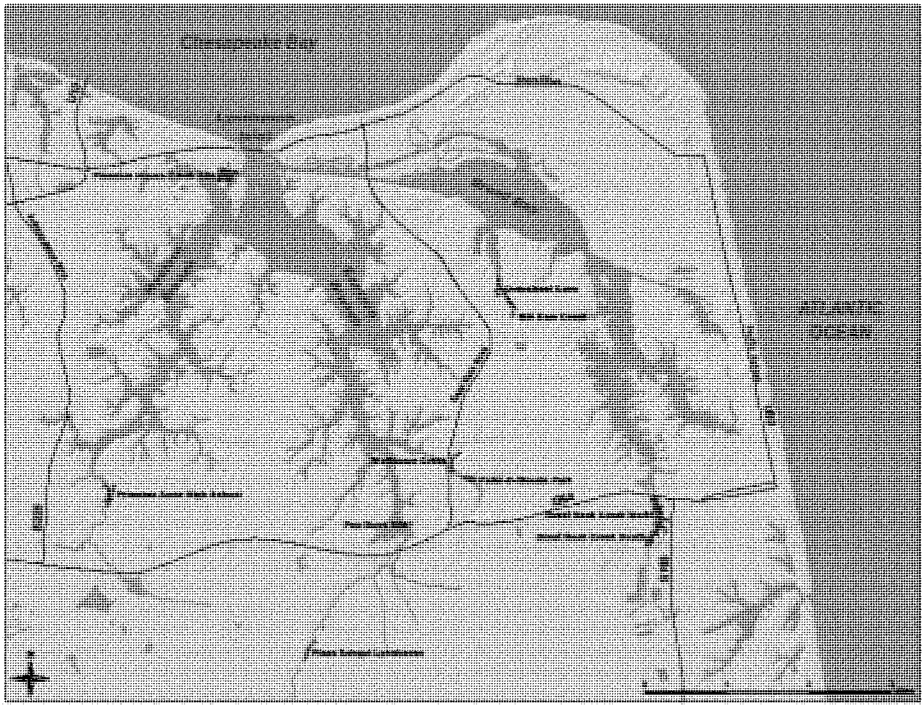


5.4.7 Wetland Restoration/Diversification. Ten areas have been identified by the sponsor and resource agencies for the reduction of invasive species. The sites identified are as follows: Overstreet Cove, Pleasure House Creek, Point O' Woods Park, Wolfsnare Creek, Brookwood and Plaza Elementary, the "Pep Boys" sites, Great Neck Creek South, Great Neck Creek North, Mill Dam Creek, and Princess Anne High School.

Overstreet Cove, Pleasure House Creek, Point O' Woods Park, Wolfsnare Creek, Brookwood and Plaza Elementary, and the "Pep Boys" sites all have similar problems associated with *P. australis*. *P. australis* populates a thin ribbon along the shoreline and resides between salt marsh that is dominated by native species and palustrine upland. In order to access the sites, either palustrine upland or native marsh plants would have to be destroyed in several different areas. Because the *P. australis* represents a relatively small footprint that would require the destruction of pristine habit in order to restore, these sites were not carried forward.

The Great Neck Creek South, Great Neck Creek North, Mill Dam Creek, and Princess Anne High School sites do not have any constructability problems associated with them. These sites were carried forward. Figure 11 shows all of the considered sites.

Figure 11. WETLAND DIVERSIFICATION SITES CONSIDERED



5.5 Formulation of Alternatives

The screening, evaluation, and modifications accomplished in Steps 1 through 3 indicate that five different measures remained under consideration: wetland creation, SAV restoration, reintroduction of Bay Scallops, construction of reef habitat, and wetland restoration/diversification. Also accomplished during step 3 of the planning process, four of the five measures, wetland creation, SAV, scallops, and reef habitat, were further differentiated into options of varying scale and size. All restoration measures that were evaluated are listed in Table 8. The detailed designs of the measures are located in Appendix A.

The IWR-Planning Suite (version 1.0.11.0) was used as a tool to aid in the formulation of alternatives by developing all possible combinations of measures under consideration. No combination was eliminated from evaluation. The wetland sites identified for wetland restoration/diversification, located at Mill Dam Creek, North Great Neck, South Great Neck, and Princess Anne High School, were analyzed using a different benefits model than the rest of the measures and were not combined with the other measures in the main cost-effective and incremental cost analysis (CE/ICA) for the study. The reasoning for using separate measures to evaluate the wetland sites is included in Section 6.2.4 of this report. A separate CE/ICA, discussed later in this report, was completed for these wetland sites. Because the scallop measure is dependent upon construction of the SAV, scallops were not considered in an alternative unless the same or greater acreage of SAV was in that plan as well. Therefore, SAV and scallops were combined into a single solution for analysis within IWR-Planning Suite. A total of 1,631 plans were taken under consideration, as well as the No Action Alternative (NAA). Each of the alternatives that remain under consideration, except the NAA, would be located within the Lynnhaven River Basin. The 1,632 alternatives carried forward for evaluation can be found in the economics appendix.

Table 8. FINAL ARRAY OF MEASURES COMBINED INTO ALTERNATIVES

Measure and Site/Scale	IWR Planning Suite Plan Code
Fish House Island (Wetland Creation) – 1 site, 3 scales	
Large Island	ISL1
Medium Island	ISL2
Small Island	ISL3
Reef Habitat – 2 sites, 5 scales	
Lynnhaven Bay and Broad Bay (normal and soft bottom)	RH1
Lynnhaven Bay and Broad Bay (normal bottom)	RH2
Broad Bay (normal and soft bottom)	RH3
Lynnhaven Bay	RH4
Broad Bay (normal bottom)	RH5

Table 8. FINAL ARRAY OF MEASURES COMBINED INTO ALTERNATIVES (Cont'd)

Measure and Site/Scale	IWR Planning Suite Plan Code
Submerged Aquatic Vegetation – 2 sites, 6 scales	
Suitable Areas Main Stem/Suitable Areas Broad Bay	SAV1,2,3
Key Areas Main Stem/Suitable Areas Broad Bay	SAV4,5,6
Suitable Areas Main Stem/Key Areas Broad Bay	SAV7,8,9
Suitable Areas Broad Bay	SAV10,11,12
Key Areas Main Stem/Key Areas Broad Bay	SAV13,14
Key Areas Broad Bay	SAV15,16
Scallops – 2 sites, 10 scales	
Suitable Areas Main Stem/Suitable Areas Broad Bay	SCL1
Key Areas Main Stem (with Suitable Areas SAV in Main Stem)/ Key Areas Broad Bay (with Suitable Areas SAV in Broad Bay)	SCL2
Key Areas Main Stem/Suitable Areas Broad Bay	SCL4
Key Areas Main Stem/Key Areas Broad Bay (with Suitable Areas SAV in Broad Bay)	SCL5
Suitable Areas Main Stem/Key Areas Broad Bay	SCL7
Key Areas Main Stem (with Suitable Areas SAV)/Key Areas Broad Bay	SCL8
Suitable Areas Broad Bay	SCL10
Key Areas Broad Bay (with Suitable Areas SAV in Broad Bay)	SCL11
Key Areas Main Stem/Key Areas Broad Bay	SCL13
Key Areas Broad Bay	SCL15
Wetland Creation – 2 sites	
Narrows to Rainy Gut	NR
Lake Windsor	LW
Wetlands Restoration/Diversification – 4 sites	
Princess Anne High School (wetland restoration)	PA
South Great Neck (wetland restoration/diversification)	SG
Mill Dam Neck (wetland restoration/diversification)	MD
North Great Neck (wetland restoration)	NG

Step 4 involves a cost effectiveness and incremental cost analysis, based on annualized costs and benefits. This step also includes a review of technical, environmental, social, and institutional considerations. See Table 9 below for a description of each alterative.

6.0 EVALUATION OF ALTERNATIVES

6.1 Costs of Construction

The costs for constructing the different alternatives, as discussed previously, were developed using the Micro-Computer Aided Cost Estimating System. These amounts represent total or fixed fee cost estimates and are a conceptual representation of the approximate order-of-magnitude costs associated with the design concepts described. These estimates were based upon representative unit costs for similar construction projects in the area. All costs used in the comparison between alternatives are in October 2010 (Fiscal Year 2011) price levels, with a 4-1/8 percent discount rate used in present value and annualized over a 50 year period of analysis with a base year of 2014. However, the recommended plan has been updated to October 2012 levels with a discount rate 3.75 percent.

6.1.1 First Costs of Construction. The costs for each alternative plan include the following: preconstruction, engineering, and design (PED); real estate; construction and plantings; construction management; contingency; and monitoring and adaptive management (AM).

PED would include such costs as field surveys and investigations, design, preparation of specifications and construction drawings; and the development, approval, and execution of the project partnership agreement. The PED costs for the wetland sites were estimated to be 12 percent of construction costs, while the PED costs for Fish House Island were eight percent, and those for reef habitat, SAV, and scallops were estimated at six percent of construction costs.

Real estate costs cover lands, easements, and rights-of-way (LER's). The real estate costs used for this analysis include private lands for the wetland sites and oyster leased area within the reef habitat, SAV, and scallop sites. Real estate assumptions and estimates have been updated since this analysis and are defined in more detail in the Real Estate Appendix.

Construction management costs cover the contractor's management, supervision, and overhead. These costs were 14 percent of the total construction costs for wetland sites, seven percent for Fish House Island, and four percent for reef habitat, SAV, and scallop sites.

A contingency cost was also added to PED, construction, and construction management costs to reflect the effects of unforeseen conditions on estimates of these costs. These costs do not allow for inflation or for omissions of work items that are known to be required; rather, they take into account any unforeseen construction problems. A 15 percent contingency was added to wetland, island, and reef habitat sites. A 25 percent contingency was added to SAV sites and a 30 percent contingency was added to scallop sites. The higher contingencies used for the SAV and scallop sites are due to the increased risk of success and need for possible reseeding or stocking of these habitats.

The aquatic systems which this study aims to improve are dynamic and complicated. It is unlikely that restoration objectives would be achieved if the proposed measures were simply constructed without further monitoring. In addition, if the monitoring shows that the project is not meeting the project objectives, adaptive management may be necessary to ensure the overall success of the project. Adaptive management (AM) and monitoring costs are described below.

AM costs are included in the construction costs for each of the alternatives. The AM costs for each of the measures are estimated at ten percent of total project costs based on the following. AM of hard reefs could range from two percent of construction costs, if removing collected sediments from the structures is required, to ten percent of construction costs. For SAV, AM could range from two percent of initial seeding costs, for signage to prevent wake zones, to five percent, in order to seed adjacent areas, and up to ten percent, for reseeding of areas that did not establish as expected. While AM for reintroduction of scallops could range from five percent of initial seeding costs, if fencing is used to prevent predation or if spat collection is required, to ten percent, in order to restock scallops in conjunction with the predation prevention measures. The AM plan for the wetland sites includes, if conditions require it, the annual application of herbicides to control the growth and spread of *P. australis* and the annual replacement of native plantings. Activities necessary to maintain the integrity of the habitat features constructed at the wetland sites, which include physical alterations of the marsh, will be planned as needed every five years.

After the total costs were determined, the cost of interest during project construction was calculated based on various periods of construction (as shown Table 9) for each of the project measures and a 4-1/8 percent discount rate. The total costs plus the costs of the interest during construction yield the investment cost. Details on the investment cost can be found in the economics appendix.

6.1.2 Monitoring Costs. Annual monitoring will be conducted for each of the measures to ensure that project objectives are being fulfilled. The cost associated with monitoring reef habitat is estimated to be $40,000 annually for the first ten years of the project, and $10,000 per year for the remainder of the 50 year period of analysis. For SAV, the cost of monitoring is also estimated to be $40,000 per year for the first five years of the project. After this period, no money has been allocated for SAV monitoring because it is anticipated that the project areas will be incorporated into the annual SAV monitoring program conducted by VIMS. Monitoring cost included for scallop reintroduction is $50,000 annually for the first five years of the project and $15,000 per year for the remainder of the 50 year period of analysis. Annual costs of $7,600 over the first ten years of the project are estimated to be the monitoring costs associated with the wetland sites. Each cost estimate accounts for the monitoring efforts required for the maximum acreage of each measure. For the alternative plans with fewer sites, and thus less acreage, the monitoring amount was reduced accordingly.

More detailed information on both monitoring and AM for each of the measures under consideration can be found in Section 9.4 of this document and the Monitoring and

AM Plan included in the Environmental Appendix attached to this report. The Monitoring and AM Plan will be more fully developed during the PED phase.

6.1.3 Maintenance Costs. After the ten year AM term is complete, it is anticipated that the application of herbicides to control the growth and spread of *P. australis* will continue to be necessary every five years for the life of the project. The cost of each herbicide application is estimated to be $1,000 for each wetlands site. This cost is included in the average annual costs as subsequently discussed.

6.1.4 Average Annual Costs. Using the total investment costs and annual costs, the average annual equivalent costs were derived for each alternative plan, based on a 50 year period of analysis, a 4-1/8 percent discount rate, and October 2010 price levels.

The total first cost, average annual cost, and construction length for the measures included in the alternatives carried forward for evaluation can be found in Table 9.

Table 9. COSTS OF MEASURES

Measure/ Site	Acres	First Cost ($)	Average Annual Cost ($)	Construction Length (months)
Wetland Creation:				
Narrows to Rainy Gut	.2	326,000	16,000	12
Lake Windsor	.2	436,000	21,000	6
Wetlands Restoration/Diversification:				
Princess Anne High School	4	908,000	45,000	6
Mill Dam Creek	1	38,000	2,000	6
Great Neck North	20	349,000	20,000	6
Great Neck South	14	333,000	18,000	6
Fish House Island (Wetland Creation):				
Large	8	4,386,000	209,000	12
Medium	5	3,377,000	161,000	12
Small	3	2,106,000	100,000	12
Reef Habitat:				
Lynnhaven Bay and Broad Bay (normal[1] and soft[2] foundation)	31	21,725,000	1,033,000	24
Lynnhaven Bay and Broad Bay (normal[1] foundation)	21	11,990,000	579,000	24
Broad Bay (normal[1] and soft[2])	21	14,731,000	690,000	12
Lynnhaven Bay	11	6,994,000	345,000	12
Broad Bay (normal[1] foundation)	10	4,996,000	236,000	12

Table 9. COSTS OF MEASURES (Cont'd)

Measure/ Site	Acres	First Cost ($)	Average Annual Cost ($)	Construction Length (months)
Submerged Aquatic Vegetation:				
Suitable Areas Main Stem/Suitable Areas Broad Bay	94	3,016,000	147,000	6
Suitable Areas Main Stem/Key Areas Broad Bay	68	2,369,000	115,000	4
Key Areas Main Stem/Suitable Areas Broad Bay	48	1,767,000	85,000	4
Suitable Areas Broad Bay	42	1,578,000	76,000	2
Key Areas Main Stem/Key Areas Broad Bay	22	883,000	42,000	2
Key Areas Broad Bay	16	664,000	32,000	1
Scallops:				
Suitable Areas Main Stem/Suitable Areas Broad Bay	94	1,439,000	84,000	6
Suitable Areas Main Stem/Key Areas Broad Bay	68	1,165,000	66,000	4
Key Areas Main Stem/Suitable Areas Broad Bay	48	887,000	49,000	4
Suitable Areas Broad Bay	42	793,000	44,000	2
Key Areas Main Stem/Key Areas Broad Bay	22	442,000	24,000	2
Key Areas Broad Bay	16	327,000	18,000	1
No action plan	0	0	0	N/A

1. "normal" foundation (in the context of Lynnhaven) refers to a medium-grain unconsolidated sandy 'hard bottom' capable of supporting the "reef-ball" structures.
2. "soft" foundation refers to mud-'unconsolidated fine silty-clay'

6.2 Description of Environmental Benefits

For this study, a wide variety of restoration measures of varying costs were carried forward for evaluation. A method was needed to relate these different measures to each other, as well as to assess their environmental impacts to the Lynnhaven River system. It was felt that a habitat unit approach would not account for the benefits accruing from the widely varying habitat types being considered for this project. For example, an acre of fish reefs plays a much different ecological role than an acre of estuarine wetlands. Additionally, the costs of the different restoration measures vary widely on a per-acre basis and a direct comparison between them using an HU approach would have resulted in abandoning several viable options. This would have greatly inhibited the study and reduced the ecological impact of the restoration activities significantly.

Instead, several basic ecological parameters were used to calculate the benefits gained by the proposed restoration activities. This non HU based approach has precedent in the bay. It has been used to scale mitigation (2002) for a large oil spill in Maryland waters of the Chesapeake Bay (Chalk Point Oil Spill) as well as to properly scale the loss of water column and associated benthic habitat for the USACE Craney Island Eastward Expansion (CIEE) project (2006).

Three environmental parameters were estimated for each of the measures related to SAV reseeding, reef habitat construction, bay scallop reintroduction, and the construction of tidal wetlands, as well as the corresponding without project conditions. These parameters were: secondary production, species diversity through a BIBI, and reduction of total suspended solids.

In order to assess whether greater importance should be given to any of these three parameters, a sensitivity analysis was completed. The sensitivity analysis demonstrated that if TSS is removed from consideration the conclusions of the original cost/benefit analysis are similar to when it is included. This is consistent with the fact that although water quality is important to habitat, it is not a direct measurement of habitat improvement. Therefore, only habitat outputs, secondary production, and species diversity were quantitatively used to justify implementation of this project.

Environmental benefits were estimated for measures related to the restoration of existing wetlands and the eradication of *Phragmites* using habitat diversity, which will described later in this section.

6.2.1 Secondary Production/Chlorophyll A. Secondary production, or the production of animal biomass, is often used as a standard measure of ecological health and productivity in ecosystem restoration work (McCay and Rowe, 2003; Peterson and Lipcius, 2003). Secondary production is typically measured as weight of living animal tissue, so weight in this instance is a measure of biological output. In ecology, productivity or production refers to the rate of generation of biomass in an ecosystem. Productivity of plants is called primary productivity, while that of animals is called secondary production. Phytoplankton are agents for "primary production," the creation of organic compounds from carbon dioxide dissolved in the water, a process that sustains the aquatic food web

For the present study, secondary production was used in two ways to quantify project benefits. First, increases in secondary production acted as a proxy for the reduction of phytoplankton in the water column. By reducing phytoplankton levels, local water clarity and quality will be improved (Paerl et al., 2003). Increasing secondary production will provide additional prey to higher trophic levels. In turn, this will increase the population of higher level predators, such as striped bass, sharks, rays, drum fish, cobia, blue fish, spotted sea trout, and weakfish, and ultimately benefit the local fisheries.

Annual secondary production biomass was estimated for each ecosystem restoration measure using ash free dry weight (AFDW). AFDW is a technique that measures organic biomass produced independent of shells, water in tissues, or other materials. An annual production/biomass estimator was used to parameterize the peak summer standing biomass to an annual production rate that varied throughout the year, with the primary driver being water temperature. This method was used by Diaz and Schaffner (1990) for their work in the Chesapeake Bay.

6.2.2 Species Diversity/BIBI. Another important metric that is often used to define the health of an ecosystem is species diversity. Negative environmental impacts typically reduce species diversity. More sensitive species are often extirpated, with increasingly less sensitive species remaining as a local ecosystem becomes more polluted until finally only a small number of pollution tolerant and/or adverse conditions tolerant species remain. Reduced productivity often is associated with the loss of diversity because pollution tolerant species are primarily small nematodes and similar aquatic worms. Many larger species, such as mussels and crustaceans, are not able to tolerate marginal environmental conditions. Because species diversity declines with increasing negative environmental conditions, improvements to the environment can be measured by the increase in species diversity. Ecosystems with higher diversity are generally regarded as more mature, less polluted, and more resilient than those with low diversity (Folke et al., 2004).

Typically, in systems with low levels of diversity where a small number of species are present, any additional loss of species is more likely to destabilize the ecosystem and perhaps alter its stable state to one that is less desirable. An example of this is the modern day Chesapeake Bay, which has essentially lost the once extensive oyster reefs that were formerly capable of exerting a significant effect on water quality in the bay (Newell 1988). In this case, the elimination of filter feeders, i.e. the American oyster, from system resulted in the increased frequency of anoxia (a total depletion of dissolved oxygen), and hypoxia (reduced dissolved oxygen). Without the oyster, unconsumed phytoplankton die and sink to the ocean floor. The decomposing plankton remove dissolved oxygen from the water column, causing water quality to drop. If habitat quality stays impaired, only the species most tolerant of poor water quality remain. The low oxygen "dead zones" seen in the Chesapeake Bay each summer are partly due to the loss of once extensive oyster reefs, which formerly consumed much of the spring phytoplankton crop in the bay.

An extensive background survey of the benthic fauna present in the Lynnhaven River was undertaken during the scoping of the proposed project (Dauer, 2007). Shallow water fish surveys were also conducted to assess nekton (Bilkovich, 2006). Both surveys showed that, in general, the Lynnhaven River is a far from pristine system. Habitat diversity is limited and species diversity is considerably lower than reference, or undisturbed, aquatic habitat.

One of the expected benefits of the proposed restoration is an increase in species diversity. For the present study, a baseline BIBI was used to calculate project benefits for the Lynnhaven River system during the scoping phase of the project (Dauer, 2007).

6.2.3 <u>Calculation of Secondary Production and Diversity Benefits</u>. Table 10 lists the environmental benefits used to justify the project. For details on how these numbers were calculated, please see the section on Ecological Benefits, in the Environmental Appendix.

<u>Table 10. ESTIMATED ANNUAL BENEFITS PER ACRE FOR EACH PROJECT MEASURE</u>

Measure	Secondary Production (kg/acre/yr)	BIBI (1-5)
Wetland creation	242	4
SAV	1,552	5
Scallops	229	3.5
Reef habitat high relief	4,457	5
Reef habitat low relief	3,601	5
Existing Condition/ Without Project	6.41	3

For each parameter, estimates for the without project condition were subtracted from the output estimated for each of the measures to determine the net benefit (or additional ecological improvement) associated with each measure. The estimates were then multiplied by the acreage of each specific site/scale for each measure to determine the total output for each specific site/scale of each measure. It is assumed that the estimated outputs is additive when specific measures are combined into the various alternatives, with no significant magnified effect from various measures being built together. Thus, the parameter output estimates for the appropriate measures were added together to determine the total benefits for each alternative. Secondary production is calculated as average annual kg per acre, and BIBI as an average annual index (1-5 scale per acre).

It was assumed that each measure would take various amounts of time after construction to achieve the full level of estimated benefits. The time for each measure to attain its full environmental potential and appropriate growth rates, as determined by literature research, was applied over a 50 year period of analysis. A linear growth rate was assumed for the construction of wetlands, reef habitat, SAV, and scallops with the same acreage as SAV. An exponential growth rate was assumed for the minimum amount of scallops when combined with the maximum amount of SAV for a given area. It is believed that the existing without project condition would stay relatively steady over the 50 year period of analysis, so the average annual outputs were assumed to be constant.

The average annual benefits for each alternative were derived by multiplying each of the parameter's annual output for each measure by the estimated percentage of output for each year of the 50 year period of analysis. The results for each year of the period of analysis were then averaged to determine the average annual benefit attributable to each scale of each measure for each of the parameters. The benefits for the appropriate measures were then summed to derive the average annual benefit for each of the parameters to determine the average annual benefits for each alternative. The average annual benefits for each measure can be seen in the Table 11.

The methodologies described above were reviewed by the ECO-PCX and were recommended for approval for use on the Lynnhaven Basin Restoration Project. A memorandum approvong the use of the models was provided by USACE Headquarters.

Table 11. AVERAGE ANNUAL BENEFITS

Measure/Site	Secondary Production (kg)	BIBI (Index Score)
WETLAND CREATION		
Narrows to Rainy Gut	29	0.18
Lake Windsor	39	0.24
Fish House Island : large	6456	8.50
Fish House Island: medium	4799	5.52
Fish House Island: small	3641	3.22
REEF HABITAT		
Lynnhaven Bay and Broad Bay (normal and soft foundation)	124185	60.75
Lynnhaven Bay and Broad Bay (normal foundation)	79068	40.15
Broad Bay (normal and soft foundation)	87681	40.04
Lynnhaven Bay	36504	20.71
Broad Bay (normal foundation)	42565	19.44
SUBMERGED AQUATIC VEG		
Suitable Areas Main Stem/Suitable Areas Broad Bay	141158	181.89
Suitable Areas Main Stem/ Key Areas Broad Bay	101984	131.42
Key Areas Main Stem/Suitable Areas Broad Bay	71677	92.36
Suitable Areas Broad Bay	62705	80.80
Key Areas Main Stem/ Key Areas Broad Bay	32502	41.88
Key Areas Broad Bay	23531	30.32
SCALLOPS		
Suitable Areas Main Stem/ Suitable Areas Broad Bay	20384	44.54
Key Areas Main Stem/ Key Areas Broad Bay	19579	42.78
Suitable Areas Main Stem/Key Areas Broad Bay	14727	32.18
Key Areas Main Stem/ Key Areas Broad Bay (with Suitable Areas SAV in Main Stem)	14279	31.20
Key Areas Main Stem/Suitable Areas Broad Bay	10351	22.61
Key Areas Main Stem/Key Areas Broad Bay (with Suitable Areas SAV in Broad Bay)	9993	21.93
Suitable Areas Broad Bay	9055	19.78
Key Areas Broad Bay (with Suitable Areas SAV)	8697	19
Key Areas Broad Bay/Key Areas Main Stem	4694	10.25
Key Areas Broad Bay	3398	7.42
No Action Plan	0	0

6.2.4 <u>Wetland Restoration/ Diversification Sites</u>. The parameters (i.e. BIBI, and secondary production) used to assess benefits gained through the implementation of the other restoration measures are not able to adequately capture environmental improvements produced through the modification of the four wetland sites. In the case of secondary production, available scientific literature presents little information on the comparative productivity of a *P. australis* versus a *S. alterniflora* dominant marsh. Studies have demonstrated that abundance within *P. australis* is dependent upon species and taxa (Chambers et al., 1999, Meyerson et al. 2000). For example, Krause et al. (1997) found that biomass of insects was high in *P. australis*, while Meyers et al. (2001) found no significant difference in nekton biomass between *P. australis* and *S. alterniflora* marshes. Currently, the shortage of quantitative productivity data makes comparisons of the two systems using secondary production infeasible.

Instead, the environmental benefits gained through the restoration/diversification of the wetland sites (Princess Anne, Great Neck North, Great Neck South, and Mill Dam Creek) were determined using a model developed by the USEPA. The model quantifies wildlife habitat value of "salt marshes based on marsh characteristics and the presence of habitat types that influence habitat used by terrestrial wildlife." The model and its application to the Lynnhaven River Basin Restoration Project have been described in detail in Appendix C.

The USEPA model quantifies habitat values based on marsh characteristics and the presence of habitat types that contribute to use by terrestrial species. The model's developers identified 79 birds, 20 mammals, and six amphibian and reptile species that utilize New England salt marsh habitat at some life stage. Habitat requirements of these species were determined through a search of published literature, unpublished reports, anecdotal information from wetland ecologists, and personal observations of the model's creators. From the available information, the developers identified common habitat types associated within salt marshes as those that were reported as being used by at least three bird or mammal species. These habitat types, as well as the habitat requirements of salt marsh fauna, form the basis of the salt marsh assessment model.

The model consists of eight wetland and landscape components that are used to assess and evaluate salt marsh wildlife habitat values (Figure 1 of the section entitled "USEPA Salt Marsh Model Description" in Appendix C). Several of the components are directly based on the different habitat types found in and around marshes or ecosystems that are linked to salt marshes. Other components reflect the anthropogenic alteration of these habitats. The remaining components take into account the size, morphology, and landscape positions of the marsh which may be important to territorial species and those that require adjacent upland habitats. The eight components are (1) marsh habitat types, (2) marsh morphology, (3) marsh size, (4) degree of anthropogenic modification, (5) vegetative heterogeneity, (6) surrounding land use, (7) connectivity, and (8) vegetation types. Each component, in turn, consists of several categories. For example, the "Habitat Type" component consists of ten categories including shallow open water, tidal flats, pannes, wooded islands, and low marsh. A complete description of each habitat component and the overall framework of this model are included in the McKinney and Wigand (2006) paper.

The model user assigns a rating of low, moderate, high, or absent to each model category. The rating is given a numerical score and a weighting factor to reflect faunal habitat requisites, which can be found in Figure 2 of the section entitled "USEPA Salt Marsh Model Description" in Appendix C. For example, one category of the habitat component involves the presence of shallow water. If open shallow water habitat makes up more than 20 percent of the marsh, the category is given a numeric score of "5." If open shallow water habitat is absent from a salt marsh, the category is given a "0." The value of each category is multiplied by a weighting factor. The output produced by the USEPA model is a numerical score that represents the overall relative wildlife habitat assessment for the marsh and is calculated by summing subtotals for each of the eight habitat components of the model (McKinney et al. 2009a). The values and weighting factors assigned to each model component are given in the table (McKinney et al. 2009a) included in the Environmental Appendix.

The maximum wildlife habitat assessment score that can be attained by a marsh when evaluated using the USEPA model is 784. The Lynnhaven River system is highly developed; therefore returning the proposed wetland sites to pristine marsh habitat unaffected by human activity is an unrealistic and unattainable restoration goal. Instead, reference sites, or marshes of high quality within the Lynnhaven River System, were evaluated using the USEPA model. The scores attained by those sites represent realistic restoration goals for this study.

The USEPA model was used to evaluate two reference sites that are located in a state park within the Lynnhaven system. The reference site (Ref Site 2) that gained the highest score received the maximum score for "Morphology," "Modification," "Surrounding Land Use," "Connectivity," and "Vegetation Heterogeneity." The site could not receive the maximum score on size because it is relatively small, as are all of the proposed restoration wetland sites. The Ref Site 2 also scores less than the maximum for "Habitat Type" and "Vegetation." Ref Site 1 is a smaller fringe marsh with some modification even though it is a healthy salt marsh. This area only received the highest score for the "Connectivity" element.

The two reference sites earned scores of 447 points (57% of the maximum possible score) and 552 points (70% of the maximum possible score) for Ref Site 1 and Ref Site 2 respectively. The reference sites received relatively low scores when evaluated using the USEPA model. This is due to the unique characteristics of the Lynnhaven River system such as the level of development, land use, and topography which supports fringe marsh instead of larger marsh meadow. As a result of the characteristics and limitations of the Lynnhaven River system, a finite improvement at each restoration site, as measured by the USEPA model, will be able to be achieved. Although the proposed restoration measures may not be able to achieve the maximum available scores of the USEPA model, the measures will still result in habitat improvements despite the restoration limitations of system.

The USEPA model was used to calculate environmental benefits that would be derived from restoration and diversification efforts at four wetland sites within the Lynnhaven River Basin throughout the 50 year lifespan of the Lynnhaven River Basin Restoration Project. The model was run twice for each site in order to produce the "Without Project" and "With Project" values. The data used to quantify the "With" and "Without Project" condition values was obtained through aerial photography collected in 2007 and site visits to all four wetland sites during the winter of 2009.

The "Without Project" condition was determined using the current conditions found at each project site. The assumption intrinsic in the uses of current conditions when developing the "Without Project" condition is that the plant community is in equilibrium and the marsh will remain relatively stable over time. The inherent weakness of this assumption is that it does not account for possible disturbances (e.g. construction and development adjacent to the marsh and sea level rise) that have the potential to alter site conditions.

The "With Project" values were developed using anticipated site conditions once restoration efforts have been completed. The future site conditions were determined using site conditions present at two high quality reference sites and the best professional judgment of the USACE biologist. The inherent weakness of forecasting future conditions is that there is no way to guarantee that optimal conditions will be established at the wetland sites. This uncertainty can be mitigated with the establishment of monitoring and AM programs, as is required by USACE policy and has been included in the Lynnhaven Project report.

The difference between the "With" and "Without Project" conditions represents the environmental benefits that will be gained through the restoration of the wetland sites. Benefit gains were due to changes to only three model components, "Habitat Type," "Vegetation," and "Vegetative Heterogeneity." The "Habitat Type" component assesses the presence of ten distinct microhabitats found within a salt marsh (i.e. shallow open water, tidal flats, pannes, trees overhanging water, high marsh, phragmites, pools, marsh-upland border, wooded islands, and low marsh) by assigning values and weighting factors to the percentage of each microhabitat present at the site. The model also assigns value to the composition of the salt marsh plant community through the "Vegetation" component. The percentage of five plant groups (aquatic plants, emergents, shrubs, trees, and vines) within the marsh unit is captured in this component. The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. An "edge" is defined as either an interface between either two adjacent plant groups, as described in the "Vegetation" component, or between a plant group and a marsh habitat type, as described in the "Habitat Type" component.

Due to limits in project size and scope, certain model components would not be affected by the proposed restoration treatments. For example, the restoration effort will have no effect on surrounding land use, marsh size, marsh morphology, or anthropogenic modification (e.g. tidal restriction and ditching). The efforts also will not affect marsh connectivity, which is "the functional relationship between adjacent habitats arising from their spatial distributions and the movement of organisms" (McKinney and Wigand, 2006). As a result, the values assigned to these components remained constant in both the "Without Project" and "With Project" conditions.

The Great Neck North site scored highest of all four sites in the "Without Project" condition and received a score of 384. This score resulted from the marsh morphology because the site falls into the "Salt Meadow/Fringe" category, which is a configuration that is considered highly valuable in the USEPA model. The site also scored highly because of the small amount of anthropogenic modification (no tidal constriction and little to no ditching) and relatively high levels of connectivity and vegetative heterogeneity. The site received a score of 436 for the "With Project" condition, which represents a 52 point gain over the "Without Project" condition score. The increase was due to two model components. The "Habitat Type" component value increased from 107 in the "Without Project "condition to 147 in the "With Project" condition, while the "Vegetative Heterogeneity" component increased from a value of 18 to 30. Average annual benefits were calculated by subtracting the score of the "Without Project" condition from the

"With Project" condition score. Restoration of the Great Neck North site would result in an average annual benefit of 52 units.

The Princess Anne site received the second highest "Without Project" condition score and the largest net benefit gain from restoration efforts. The site warranted 304 points for the "Without Project" condition and 389 points for the "With Project" condition. In addition to the high benefit score, this site has the added benefit of providing a wetland restoration in a different area of the Basin than the other wetland sites as well as potentially serving as a STEM site (Science Technology, Engineering and Math) for educational opportunities as it is located adjacent to a high school. The site is a relatively small fringe marsh located in a highly developed area, so it received low scores for the "Size Class," "Morphology," "Connectivity," and "Surrounding Land Use" components. However, the site is not ditched and has little to no tidal restriction. Even though *Phragmites* dominates the lower marsh, the site exhibits a relatively high level of vegetative heterogeneity. The site received high scores on the "Vegetative Heterogeneity" and "Habitat Type" components. The model components which accounted for the change between the "With Project" and "Without Project" conditions were the same as for the Great Neck North site. "Habitat Type" increased from 107 to 178, and "Vegetative Heterogeneity" increased from 18 to 30. The environmental impact resulting from the restoration of the Princess Anne site is predicted to be the greatest of all of the four wetland sites, with an estimated average annual benefit of 85 points over the life of the project.

The current conditions at the Great Neck South site resulted in a low "Without Project" condition score of 286. The marsh is a relatively large "salt meadow/fringe" exhibiting some habitat diversity within the buffer zone surrounding the site, so it received high values for the "Morphology" and "Connectivity" components. The site consists almost entirely of *Phragmites*, so "Habitat Type" and "Vegetative Heterogeneity" scores were low. The "With Project" conditions increased 75 points, to a score of 361. The components that were responsible for the change were "Habitat Type" (from 53 to 113), "Vegetative Heterogeneity" (from 6 to 18), and "Vegetation" (from 20 to 23). The average annual environmental benefit realized through the restoration of the Great Neck South site is estimated to be 75 points.

The final site, Mill Dam Creek, had the lowest values both prior to and after the completion of the restoration efforts, earning 282 for the “Without Project” condition and 348 for the “With Project” condition. The site received low scores for most model components in its current condition because the marsh is a small fringe marsh that is completely dominated by common reed. The “Size Class,” “Morphology,” and “Vegetative Heterogeneity” components received the lowest values. The change in condition between “With Project and “Without Project” was observed in the “Habitat Type” (from 94 to 148) and the “Vegetative Heterogeneity” (from 6 to 18) components. Implementation of the project would result in an estimated average annual benefit of 66 points.

The average annual environmental benefits calculated using the EPA model can be found in the following table for each of the wetland restoration sites. Spreadsheets containing the individual component values for each site are included in Appendix C.

The USEPA model described above was reviewed by the ECO-PCX and was recommended for approval for use on the Lynnhaven Basin Restoration Project. A memorandum approving the use of the model was provided by USACE Headquarters.

Table 12. WETLANDS WITH PHRAGMITES ERADICATION SITES AVERAGE ANNUAL BENEFITS

Wetlands with *Phragmites* Eradication Site	Net Average Annual Wetland Benefits (With Project – Without Project Condition) (Assessment score on a 784-point scale)*
Princess Anne High School	85
Mill Dam Creek	66
Great Neck North	52
Great Neck South	75
No Action Plan	0

*Severely impaired marshes can receive scores below 100; while reference sites, which are high quality and relatively unimpaired, in the Lynnhaven River Basin received scores up to 552.

7.0 COMPARISON OF ALTERNATIVE PLANS

Alternative plans developed from the measures and scales, as shown in Section 5, are compared with each other in order to identify the plan to be recommended for implementation. A comparison of the effects of various plans is made and tradeoffs among the differences observed are documented to support the final recommendation. The effects include a measure of how well the plans do with respect to planning objectives, including NER benefits and costs. Effects required by law or policy and those important to the stakeholders and public are also considered. In the evaluation process, the effects of each measure and scale were considered individually and compared to the without project condition. In this step, plans are compared against each other, with emphasis on the important effects or those that influence the decision-making process.

In order to make more informed decisions with regard to the development and eventual selection of the NER Plan, a cost effectiveness analysis and incremental cost analysis were conducted, as required by USACE Planning Guidance, utilizing the IWR-Planning Suite Software (version 1.0.11.0). Cost effectiveness analysis identifies the plan or plans that produce(s) the greatest level of environmental output for the least cost. The environmental outputs, however measured, in turn reflect the environmental benefits, such as biological diversity, fish and wildlife habitat, and nutrient cycling, provided by the plan or plans. Incremental cost analysis examines the changes in costs and the changes in environmental outputs for each additional increment of environmental output. The Best Buy Plans represent those plans that produce the greatest increases in environmental outputs for the least increases in cost.

7.1 Multivariable Analysis

The average annual costs and average annual benefits identified previously were used to conduct cost effectiveness and incremental cost analyses for the 1631 alternative plans, as discussed in section 5.5, as well as the No Action Plan. In the case of alternative plans that include measures related to SAV, reef habitat, scallops, and wetland creation, three separate parameter outputs were initially used to indicate the environmental benefit associated with each of the alternatives under consideration.

7.1.1 Sensitivity Analysis on Weighting of Parameters. The original cost/benefits analysis was completed using three environmental parameters: secondary production, species diversity, and TSS. In order to assess the effect on the outcome of the CE/ICA if greater importance was given to any of the three original benefit parameters (shown in detail in Appendix B), a sensitivity analysis was performed to evaluate the effect of various weights on the results of the analysis. The analysis was rerun with the following weights;

- 50 percent TSS reduction, 50 percent secondary production, 0 percent BIBI
- 0 percent TSS reduction, 50 percent secondary production, 50 percent BIBI
- 50 percent TSS reduction, 0 percent secondary production, 50 percent BIBI
- 100 percent weight on TSS reduction
- 100 percent weight on Secondary Production
- 100 percent weight on the BIBI.

Table 13. DESCRIPTION OF ALTERNATIVES

(See Table 18 for Wetland Restoration/Diversification)

Alternative	SAV	Scallops	Reef Habitat	Wetland Creation
A	Suitable Areas in Main Stem and Broad Bay	Key Areas in Main Stem and Broad Bay	None	None
B	Suitable Areas in Main Stem and Broad ay	Key areas in Main Stem and Broad Bay	Broad Bay on normal foundation	None
C	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal foundation	None
D	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	None
E	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design)
F	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design)
G	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design), and Lake Windsor
H	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design), Lake Windsor, Narrows to Rainy Gut

Table 14. SUMMARY OF SENSITIVITY ANALYSIS ON WEIGHTING (BEST BUY PLANS)

Best Buy Plans	Equal Weights (Main Analysis)	100% TSS	100% SP	100% BIBI	50% TSS/50%SP	50%TSS/50%BIBI	50%SP/50%BIBI
A	x		x	x	x	x	x
B	x	x	x	x	x	x	x
C	x	x	x	x	x	x	x
D	x	x	x	x	x	x	x
E	x	x	x	x	x	x	x
F**	x		x	x	x	x	x
G**	x		x	x	x	x	x
H**	x	x	x	x	x	x	x
I*			x				
J*		x					
K*			x				
L*		x					
M*		x					

*Plans not carried forward for consideration because only identified as best buy plan by one of the sensitivity analyses and not by the main CE/ICA.
**Plan not carried forward for consideration because of very high incremental costs

It was specifically identified through the analysis, using only secondary production and species diversity (0 percent weight on TSS reduction, 50 percent weight on secondary production, and 50 percent weight on BIBI), that the resulting best buy plans are the same when the benefits are analyzed with or without the TSS reduction parameter. This is because the MCDA scores, though different with and without inclusion of the TSS parameter, follow the same positively increasing pattern in output associated with each alternative plan under consideration. The following table shows the results of the incremental cost analysis with only secondary production and species diversity (0 percent weight on TSS reduction, 50 percent weight on secondary production, and 50 percent weight on BIBI). In addition, the following figure displays this information graphically. Therefore, as the TSS is not necessary for differentiating plans, and as it more of an indicator of water quality rather than a measurement of habitat improvement, it was not used to justify the project and will not be discussed further in this analysis.

Figure 12. SECONDARY PRODUCTION AND BIBI BEST BUY PLANS

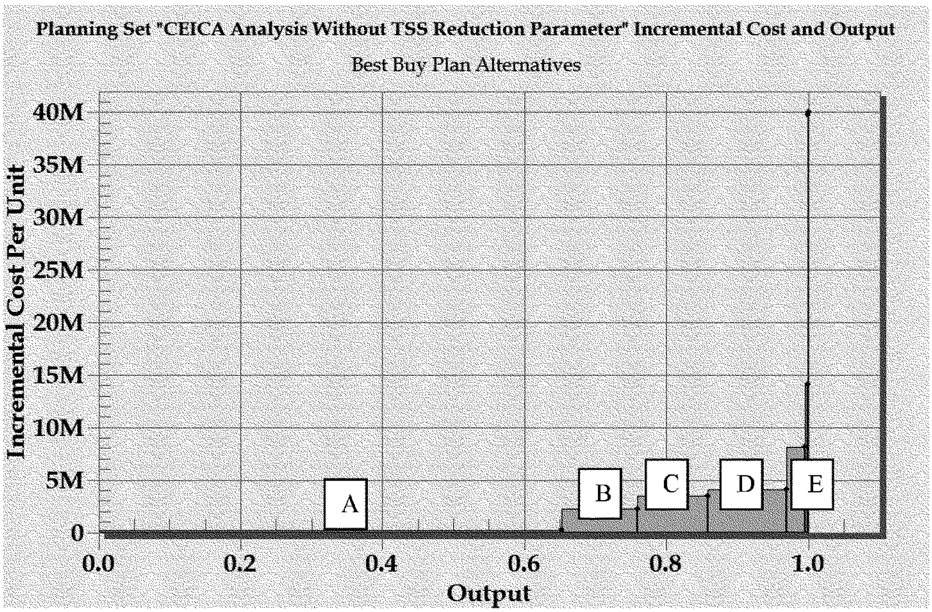


Table 15. RESULTS OF BEST BUY ANALYSIS

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
A	0.65	171,000	262,000	171,000	0.6544	262,000
B	0.76	407,000	536,000	236,000	0.1057	2,234,000
C	0.86	750,000	874,000	343,000	0.0974	3,517,000
D	0.97	1,204,000	1,242,000	454,000	0.1119	4,055,000
E	0.99	1,413,000	1,420,000	209,000	0.0254	8,233,000
F	1.00	1,473,000	1,474,000	60,000	0.0044	13,792,000
G	1.00	1,494,000	1,494,000	21,000	0.0005	44,465,000
H	1.00	1,510,000	1,510,000	16,000	0.0004	44,846,000

7.1.2 Weighting of Values for MCDA. As discussed in section 7.1.1 MCDA allows for the use of weights to reflect the importance of each parameter under evaluation. The sensitivity analysis performed confirmed the assumption that neither secondary production nor BIBI have a significantly greater bearing on the overall value of the system. Due to this, and their joint, central importance to the ecological benefits model, it was decided to weight them equally.

Additionally, the Chesapeake Bay Program has also recently been given more attention by the current administration. EO 13508, Chesapeake Bay Protection and Restoration, outlines a strategy to improve the water quality, restore and protect watershed habitat, sub-aqueous habitat, and organisms that live in it. The selected parameters aid in meeting goals outlined in the Action Plan associated with EO 13508.

7.1.3 Multi Criteria Decision Analysis. Typically, CE/ICA is conducted on one benefit output and one cost output. Therefore, the CE/ICA analysis for this study was not as straightforward as with other studies. The Multi-Criteria Decision Analysis Module (MCDA) of IWR-Planning Suite was used as a means to combine the multiple parameters into one benefit metric to compare with costs in CE/ICA.

The MCDA Module of IWR-Planning Suite provides a numerical method for comparing benefit parameters with inconsistent units. The benefit values entered into the MCDA are evaluated as a matrix, with each row being an alternative and each column a benefit category. All of the values in the matrix are normalized and ranked to determine a single score for each alternative (or row) under evaluation. For this evaluation, the values were ranked using the weighted scoring ranking method and normalized using the normalization to range method (USACE Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010).

The MCDA module described above has been reviewed by the ECO-PCX and has been recommended for approval for use on the Lynnhaven Basin Restoration Project. A memorandum approving the use of the model was provided by USACE Headquarters.

7.1.4 <u>Ranking Method</u>. Ranking methodology aims to find the relative minimum and maximum of each benefit category for all of the rows in a matrix (or planning set) in order to rank the rows from the optimal solution to the least optimal solution. There are several ranking methods available for use in the MCDA module: weighted scoring, compromise programming, and outranking. The weighted scoring technique, the ranking method used for this analysis, compares plans to one another and assumes higher benefit values result in a more beneficial plan. This particular ranking method was chosen for use due to its lack of complexity as compared to the other ranking methods. Weighted scoring of a planning set is performed as follows: values are normalized; values for maximized categories are multiplied by designated weights; weights for minimized categories are converted to negative and then multiplied by the criterion (benefit value); raw weighted values for alternatives are generated by adding together the score values for a particular row; these scores are then normalized once again to generate scores that fall between 0 and 1(USACE Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010).

7.1.5 <u>Normalization Method</u>. Normalization allows benefit categories with different units of measurement to be evaluated together in one analysis. The weighted scoring ranking method allows for use of three different normalization methods: normalization to maximum, normalization to range, and normalization to percent of total. The normalization to range method was chosen for this evaluation since this method assures that each normalized value will be between zero and one; whereas the other normalization methods to not guarantee this. With the normalization by range method, the normalized value is calculated as follows: $v = (a - \min a) / (\max a - \min a)$, where a = "raw" value of criterion (USACE Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010).

7.1.6 Cost Effectiveness and Incremental Cost Analysis on MCDA Scores. A cost effectiveness and incremental cost analysis was conducted on the scores derived using the MCDA weighted scoring method with equal weighting. The results of the cost effectiveness analysis using the MCDA weighted scoring method, with equal weighting, indicated 123 of the considered plans to be cost effective. The cost-effectiveness plans can be found in Table B-7 in Appendix B to this report. Each of these plans is the least-costly means of providing the associated level of output or benefit.

After conducting the cost effectiveness analysis, incremental cost analysis examines the changes in costs and changes in environmental benefits for each additional increment of output. For each best buy plan there are no other plans that will give the same level of output at a lower incremental cost. The plan with the lowest overall average cost per unit of output, advancing from the No Action Plan (NAP), is the first Best Buy Plan. After the first Best Buy Plan is identified, subsequent incremental analyses are done to calculate the change in costs and change in outputs of advancing from the first Best Buy Plan to all of the remaining (and larger) cost-effective plans. The results of the incremental cost analysis using the MCDA weighted scoring method indicated eight of the considered plans, in addition to the no action plan, to be best buy plans.

7.2 Wetland Restoration/Diversification Sites

As discussed previously, the wetlands restoration sites were valued using a different parameter than the rest of the restoration measures. Therefore, a separate

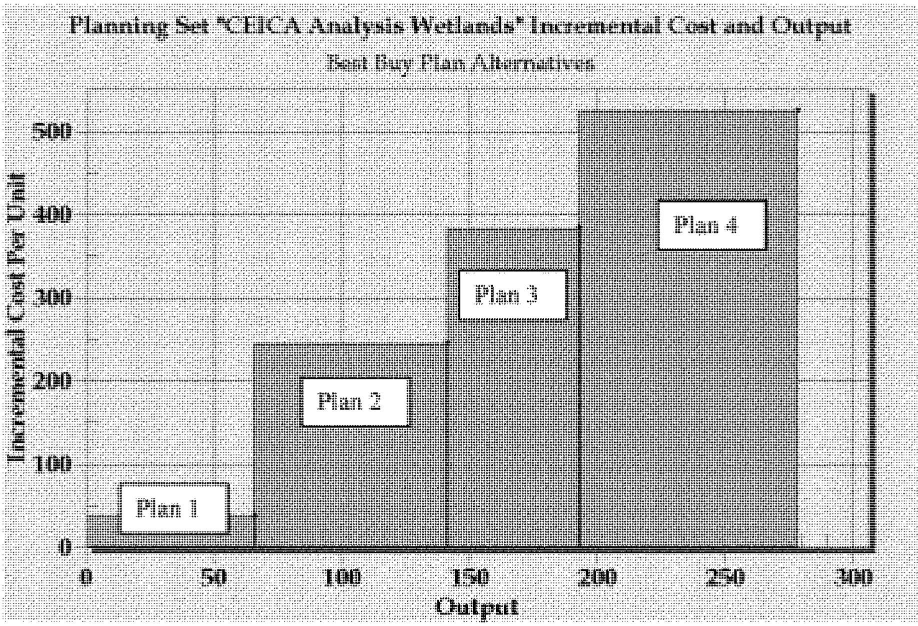
CE/ICA was conducted on just these sites. The CE/ICA for the wetland restoration sites was relatively straightforward, since only one output parameter was used to quantify the environmental benefits. Construction of each of the four sites is not considered mutually exclusive, so all possible combinations of the four sites were analyzed, resulting in a total of fifteen plans in addition to the no action plan. The results of the cost-effective analysis indicate six plans in addition to the no action plan to be cost effective. The cost-effective plans can be found in Table B-16 of Appendix B to this report. Each of these plans is the least-costly means of providing the associated level of output or benefit for the wetland restoration sites.

After conducting the cost effectiveness analysis, incremental cost analysis examines the changes in costs and changes in environmental benefits for each additional increment of output. The results of the incremental cost analysis on the wetland restoration sites indicated four of the considered plans in addition to the no action plan to be best buy plans. Table 16 summarizes the information from the incremental cost analysis of the alternatives and Figure 13 displays the information graphically.

Table 16. RESULTS OF INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Wetland Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Incremental Output	Incremental Cost per Output
No Action Plan	0.00	0.00				
1 - Mill Dam Creek	66.00	2,400	36	2400	66.0000	36
2 - Mill Dam Creek and South Great Neck	141.00	20,800	148	18,300	75.0000	244
3 - Mill Dam Creek, South Great Neck, and North Great Neck	193.00	40,700	211	19,900	52.0000	383
4 - Mill Dam Creek, South Great Neck, North Great Neck, and Princess Anne	278.00	85,300	307	44,600	85.0000	525

Figure 13. WETLANDS ANALYSIS BEST BUY PLANS



8.0 SELECTION OF A NATIONAL ECOSYSTEM RESTORATION PLAN

8.1 Plan Selection

When selecting a single alternative plan for recommendation from all those that have been considered, the criteria used to select the NER Plan include all the evaluation criteria discussed previously. Selecting the NER Plan requires careful consideration of the plan that meets planning objectives and constraints and reasonably maximizes environmental benefits while passing tests of cost effectiveness and incremental cost analysis, significance of outputs, acceptability, completeness, efficiency, and effectiveness.

8.2 Multivariable Analysis

The results of the cost effective and incremental cost analysis using the MCDA score derived using secondary production and species diversity is used in selection of an

NER plan. For plans including measures related to SAV, reef habitat, scallops, and wetland construction, the results of the cost effectiveness and incremental cost analyses indicate there are eight Best Buy Plans in addition to the No Action Plan. The results of this analysis were compared in conjunction with the results of the original analysis and the other sensitivity analyses, details of which can be found in Appendix B. The incremental cost per output was considerably high for the three highest level best buy plans identified. Therefore, the alternative plans carried forward for consideration were narrowed down to the five best buy plans described in Table 17 below.

Of the Best Buy Plans, Alternative D best meets the planning objectives while reasonably maximizing environmental benefits. This plan includes the Suitable Areas SAV in both Broad Bay and the main stem, Key Areas scallops in both Broad Bay and the main stem, and both low relief reef habitat and high relief reef habitat (on normal and soft foundations). In addition to being identified as a best buy plan by the CE/ICA on the MCDA score derived using equivalent weights, this plan was also identified as a Best Buy Plan by all of the other CE/ICAs conducted for the sensitivity analysis on the weights applied to each benefit parameter. Specifically, this plan was identified as a Best Buy Plan by the CE/ICA on the MCDA score derived with equal weights on the secondary production and BIBI, with no weight on the TSS reduction.

The increase in average annual output outweighs the additional average annual cost for Alternatives A, B, C, and D for all of the analyses, whereas this is not the case for Alternative E. For the MCDA analysis with 50% weighting on secondary production, and 50% weighting on species diversity, the incremental cost per output for Alternative E is $4,200,000 more than for Alternative D, which, in turn, would only increase secondary production by about 6,500 kg more on average annually. In addition to the considerably higher incremental cost per unit of output, the plan including the Fish House Island restoration has several significant risks involved with construction.

The intent of the Fish House Island Plan is to restore pre-existing vegetated wetland habitat. Several conditions related to the adjacent Federal navigation channel and inlet orientation would present significant challenges to the constructability and maintenance of the proposed island. Swift currents in the vicinity would require substantial shoreline armoring to confine fill material within the historic footprint. The orientation of the inlet opening to the north allows a higher percentage of larger northeast waves to impact the proposed island. Given the magnitude of all of these risks, Alternative E was therefore removed from consideration.

Table 17. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

Alternative plan	Code	Description
A	SAVSCL2	Suitable Areas SAV in Main Stem and Broad Bay and Key Areas Scallops in Main Stem and Broad Bay
B	SAVSCL2RH5	Suitable Areas SAV in Main Stem and Broad Bay and Key Areas Scallops in Main Stem and Broad Bay And Reef habitat in Broad Bay on normal foundation sites.
C	SAVSCL2RH2	Suitable Areas SAV in Main Stem and Broad Bay, Key Areas Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on normal foundation sites.
D	SAVSCL2RH1	Suitable Areas SAV in Main Stem and Broad Bay, Key Areas Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites.
E	SAVSCL2RH1ISL1	Suitable Areas SAV in Main Stem and Broad Bay, Key Areas Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, and Fish House Island (Large Design).

Figure 14. LOCATIONS OF PLAN A

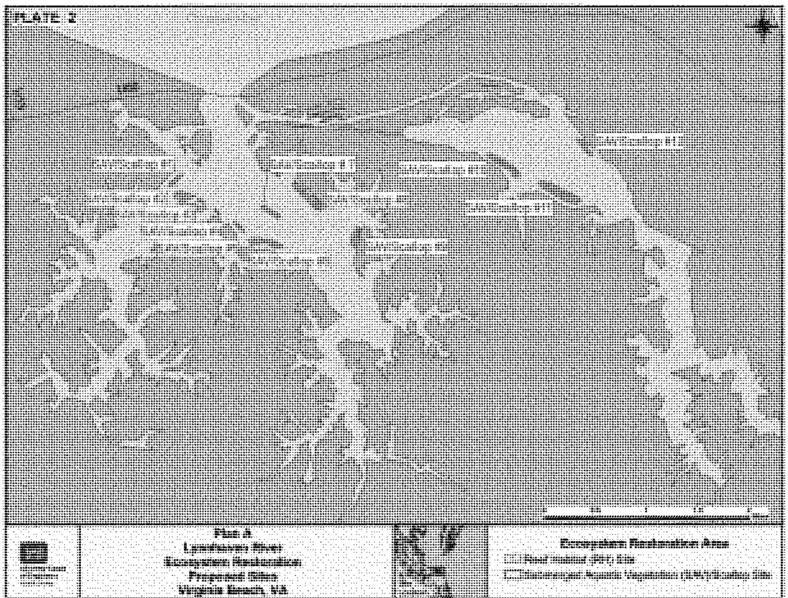


Figure 15. LOCATIONS OF PLAN B

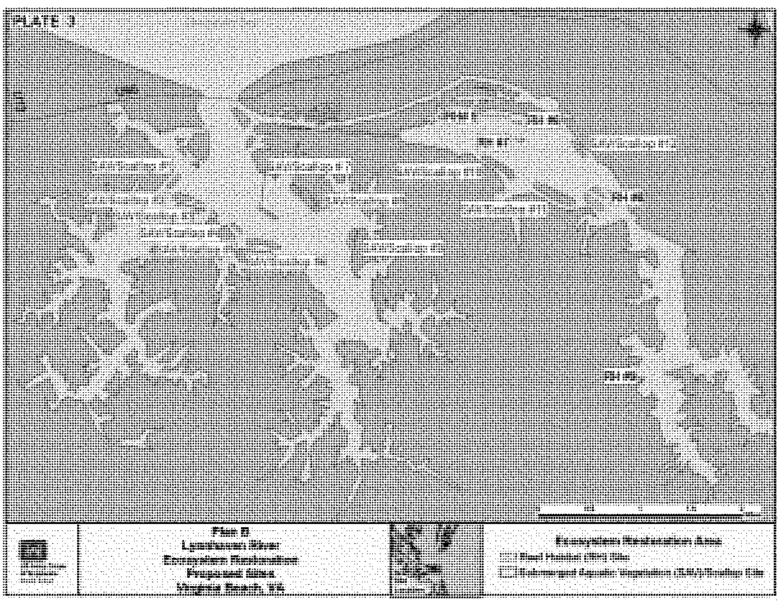


Figure 16. LOCATIONS OF PLAN C

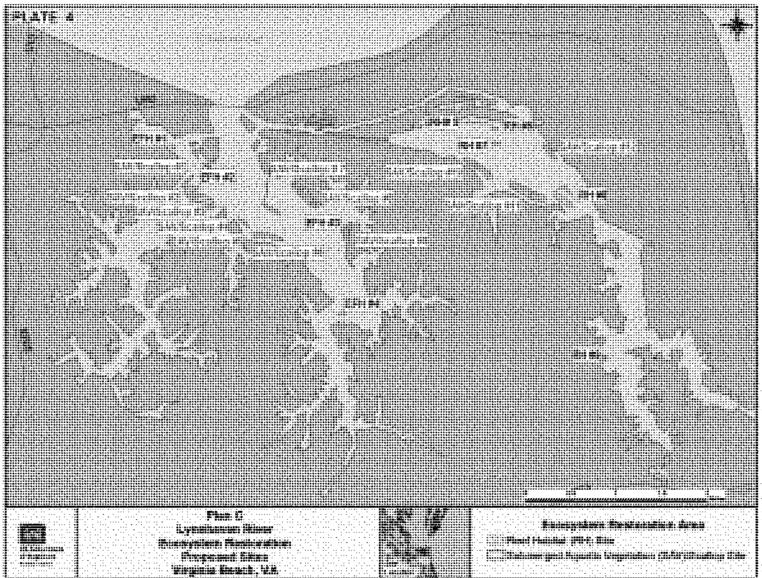


Figure 17. LOCATIONS OF PLAN D

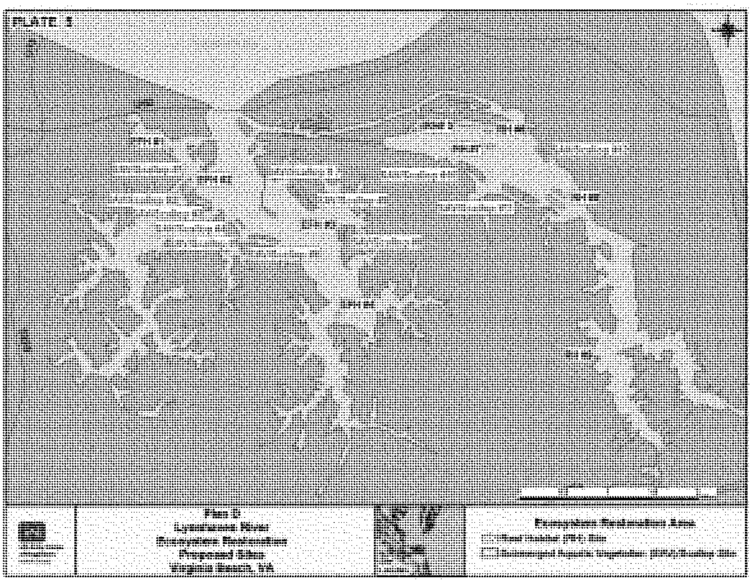
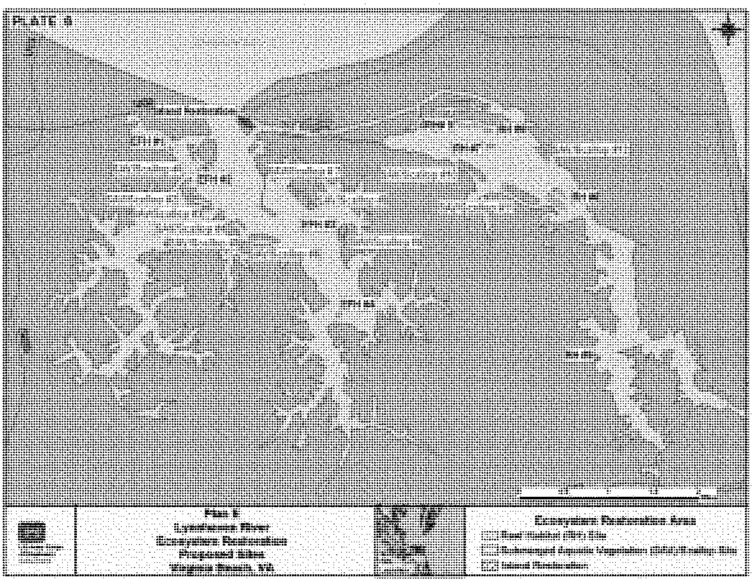


Figure 18. LOCATIONS OF PLAN E



Alternative A includes only measures of SAV and scallops. While this alternative is efficient and effective, it is not complete in terms of fully meeting the objectives of the project. Because of this, the plan is not as acceptable as the other alternatives carried forward for consideration. Alternative A was therefore removed from consideration.

The average annual incremental cost per unit of output for Alternative D is approximately $540,000 more than the next lower output Best Buy Plan Alternative C. However, this plan includes both the normal and soft foundation sites for the reef habitat rather than just the normal foundation sites. Inclusion of these soft foundation sites increases secondary production by 45,000 kg more on average annually. While the average cost per acre to construct the reef habitat sites with soft foundations is significantly higher as compared to the reef habitat sites with normal foundations, it is still worthwhile to produce this additional level of output when considered along with all the other components of the restoration project.

In addition to the quantified benefits of the reef habitat sites, there are additional benefits that would be realized by the reef habitat sites with soft foundations. These particular sites would require geotextile matting with small stone to stabilize the bottom in order to prevent subsidence of the reefs. These mats essentially function as a thin riprap layer and increase the size of the footprint of reefs placed on top of them. This underlying structure provided by the mats creates hard bottom habitat in an area currently lacking it which is expected to improve secondary production.

Hard clams are a benthic invertebrate that contribute the majority of the secondary production where they can be found. They prefer harder substrates, such as firm sand, rocky bottom, or shells, over softer silts or clays. Clams (*Mercenaria mercenaria*), have also been found in greater densities around hard structures as compared to open substrate and are often found burrowing under and adjacent to oyster reefs. As a result, it is expected that these large bivalves would be found in greater numbers around the reefs with mats than the reefs without mats. Such a difference could add considerable biomass to the borders of the fish reefs and because the clams are benthic filter feeders, it could add to the ecological benefits gained from the reef habitat constructed with geotextile matting. During routine survey work to find hard bottom areas for construction in the Lynnhaven River, it was noted that *Mercenaria mercenaria* were found in much greater numbers in areas that had shell present than in nearby clay/silt bottom habitat. Based on this observation, it is reasonable to expect similar benefits around the edges of the supporting mats for the reefs built on softer bottom habitat. Additionally, other sessile benthic organisms may live in higher numbers on the stone itself or in between the small rocks that provide shelter from predation as well as hard substrate for attachment by sessile invertebrates.

8.3 Wetland Restoration/Diversification Sites

The results of the cost effectiveness and incremental cost analyses on the wetland restoration sites indicate there are seven cost-effective plans, of which there are four Best Buy Plans in addition to the No Action Plan.

Table 18. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

Alternative plan	Code	Description
1	PA0SG0MD1NG0	Mill Dam Creek site.
2	PA0SG1MD1NG0	South Great Neck and Mill Dam Creek sites.
3	PA0SG1MD1NG1	South Great Neck, Mill Dam Creek, and North Great Neck sites.
4	PA1SG1MD1NG1	Princess Anne High School, South Great Neck, Mill Dam Creek, and North Great Neck sites.

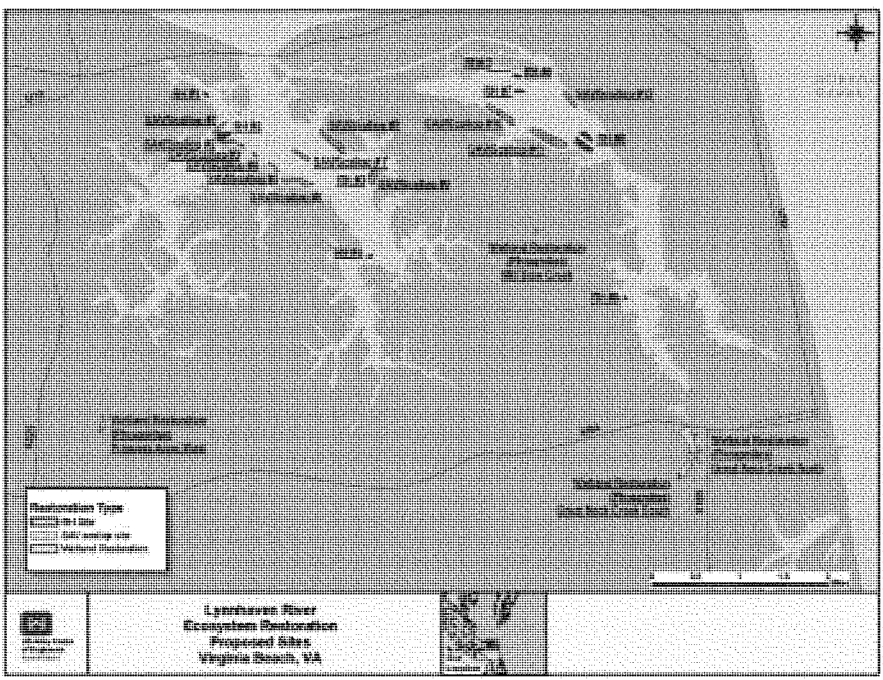
The results of the CE/ICA were analyzed to determine the plan with the best value of the plans evaluated. Of the Best Buy Plans, Alternative 4, with construction of all four wetlands with *P. australis* eradication sites, best meets the planning objectives while reasonably maximizing the environmental benefits. There is a significant difference in incremental cost per output between the alternative with construction of just Mill Dam Creek and the other alternatives. However, the Mill Dam Creek site is limited to less than one acre. When comparing the cost per acre of the most expensive site, the Princess Anne site, to the construction cost of the average wetland in the study area, the cost per acre of the Princess Anne site, which is just over $200,000, is seen as a considerable value. The Mill Dam Creek, North Great Neck, and South Great Neck sites would be considered an exceptional value in this comparison since the construction cost for each is under $40,000 per acre.

8.4 Recommended Plan

The Recommended Plan is plan D.4, which is Plan D, described previously in the MCDA analysis, and Plan 4, described previously in the wetlands analysis. Plan D.4 includes the maximum SAV in main stem and Broad Bay, minimum scallops in main stem and Broad Bay, reef habitat in Broad Bay and Lynnhaven Bay, and all four wetland with *P. australis* eradication sites. The locations included in this plan are shown in Figure 19.

The ecological benefits estimated for the Recommended Plan include an average annual increase in secondary production of 285,000 kg and an average annual increase in the BIBI per acre of approximately two index points (on a scale of 1-5). The wetland restoration component of the Recommended Plan is expected to increase the USEPA Marsh Assessment Score by an average of approximately 70 for each site restored.

Figure 19. LOCATIONS OF THE RECOMMENDED PLAN



8.5 NER Plan Evaluation

The project presented in the Recommended Plan is worth the cost because it will restore significant ecological resources that are currently scarce in the Lynnhaven River Basin. The Recommended Plan is acceptable, efficient, effective, and complete. Because it is a highly developed Basin, there are very limited opportunities to restore this river to a measure of its historical conditions. The enormous community and political support and the identification of a feasible restoration plan that will provide tangible ecosystem benefits all underscore the importance this project.

8.5.1 Acceptability. The Recommended Plan is acceptable to the non-Federal sponsor, the local communities, and local non-government organizations within the Lynnhaven River Basin. The NFS has provided a letter of support for the project. In addition, members of local non-governmental organizations and partnering agencies have been involved in the planning of this project from the beginning, either as members of the steering committee or as technical experts.

The Recommended Plan also complies with Federal, State and USACE environmental laws, regulations and policies. A list describing the applicable legislation and USACE compliance with each is included in Section 11.14 "Environmental Laws, Statutes, Executive Orders, and Memorandum".

8.5.2 Efficiency. The Recommended Plan passes tests of cost effectiveness and incremental cost analyses (CE/ICA). As shown through the preceding section on CE/ICA, the maximum SAV restoration (94 acres), reef habitat restoration (31.5 acres), and bay scallop restoration (22 acres) represent a cost effective and "Best Buy" plan. This plan has the lowest cost for the estimated level of output this plan would produce and is incrementally justified.

The four wetlands sites represent a cost effective means of restoring approximately 38 acres of wetlands and no other plan yields the same level of wetlands for less cost. The Recommended Plan is also a "Best Buy" plan, incorporating the four wetlands restoration sites. Using the wildlife habitat value of New England salt marshes assessment methodology, it has the lowest incremental costs per unit of output to achieve 38 acres of wetlands restoration and diversification.

8.5.3 Effectiveness. The Recommended Plan is effective because it addresses the problems and needs in the Lynnhaven River Basin. The restoration projects and associated benefits that the plan will provide are spread over a large geographic area in the system. The projects have been designed to be interconnected with components of the natural systems in the Lynnhaven River Basin and to be self sustaining.

8.5.4 Completeness. The Recommended Plan is complete in that it meets all of the objectives and may be constructed and maintained. The restoration efforts are located throughout the Lynnhaven River Basin and are comprised of different facets of the Lynnhaven River ecosystem functions.

8.6 NER Plan

The Recommended Plan, D.4, is the NER Plan. This plan meets the criteria of acceptability, effectiveness, efficiency, and completeness. This plan meets all of the planning objectives and is supported by the non-Federal sponsor.

9.0 PLAN DESCRIPTION

The NER Plan, D.4, is considered the Recommended Plan and will be identified as the Recommended Plan throughout the remainder of this document. This plan includes the maximum SAV in main stem and Broad Bay, minimum scallops in main stem and Broad Bay, reef habitat in Broad Bay and Lynnhaven Bay, and all four wetland with *P. australis* eradication sites. The costs, sites, and outputs of this plan are described in detail in the following sections.

9.1 Project Costs

Since the economic analysis discussed previously was completed using FY 2011 price levels, the costs for the Recommended Plan presented in this section have been updated to the current price level of FY 2013 and a base year for construction of 2017. The total project first cost of the Recommended Plan, which includes costs for preparation of the plans and specifications, construction costs, construction management of the project, and lands, easements, rights of way, relocations, and dredge material disposal areas (LERRD) is estimated to be approximately $34 million. A summary of these costs can be found in Table 20. The current detailed cost estimate, which was certified by the Cost Engineering Mandatory Center of Expertise, can be found in Appendix A. A detailed description of the LERRD requirements and associated costs can be found in the Real Estate Appendix, as well as the subsequent section 9.3.

Table 19. TENATIVELY SELECTED PLAN PROJECT COSTS

Cost	Total ($)
Plans and specifications	2,663,000
Construction	28,898,000
LERRD	725,000
Construction management	2,127,000
Total project first cost	34,413,000

9.2 Project Measures

9.2.1 Wetland Restoration/Diversification. Due to the unique characteristics of each wetland site and the limitations of the Lynnhaven Restoration Project, the anticipated outcomes for all four wetlands sites are not identical. Two different project objectives, "habitat restoration" and "habitat diversification," were developed. The proposed methods to be employed at each site were tailored to achieve the individual project goal.

9.2.1.1 ***Salt Marsh Restoration*** - The project objectives for the Princess Anne (PA) and the Great Neck North (GNN) Sites are to restore the indigenous salt marsh community and reduce the population of invasive plant species, *Phragmites australis,* growing on site. Although *P. australis* marsh restoration projects are extremely challenging, certain sites' features support the achievement of this goal. For example, even though *P. australis* has been introduced, each site has supported a native salt marsh community in the past. Other site characteristics that support restoration efforts include the lack of tidal restriction and the general accessibility that will allow heavy equipment to be used during the restoration effort.

Habitat restoration will involve both physical alteration of the site and herbicide application. Within areas that are dominated by *P. australis* and can be accessed by heavy construction equipment, the *P. australis* stands will first be treated with herbicide approved for wetland use to kill existing foliage. Then, approximately two to four feet of the upper peat layer will be excavated to remove as much *P. australis* material, including rhizomes, roots, and foliage, as possible in order to prevent recolonization and to grade the site to the elevation optimal for the growth of *Spartina alterniflora,* a native salt marsh grass that inhabits the lower marsh. Materials generated from sediment excavation activities at the wetland restoration sites will be disposed of at landfill facilities and be evaluated as solid waste in accordance with HTRW guidance as appropriate. Features such as shallow pools, upland islands, and channels will be created to increase the diversity of the marsh habitat and to allow seawater to flood the area. Finally, the bare substrate will be planted with lower marsh plants, such as *S. alterniflora,* upper marsh plants, e.g. *Spartina patens,* and marsh bushes species including *Iva frutescens* and *Baccharus halimfolia.* Other marsh plants may be used in this project as appropriate. The plantings will be completed in April, May, or June in order to have the highest probability of success. Plant spacing for the restoration efforts will be between two feet and 1.5 feet on center. Exclusion techniques will be used to protect the young plants from grazing by geese and other herbivores. Best practices will be used to stop erosion and control sediment.

In areas that cannot be reached with heavy equipment or where small patches of *P. australis* are present, aquatic herbicides will be applied either through aerial or manual application. If annual temperatures and precipitation are within normal ranges, herbicide application will occur during the last two weeks of September. Herbicide use during the late fall will reduce collateral damage to nontargeted plant species because *P. australis* remains active for approximately two weeks after native plant species go dormant. If rainfall and temperatures are lower than normal, the spraying schedule will be reassessed.

Prior to any treatment resulting in the eradication of *P. australis*, the existing plant populations must be examined to ensure that the plants are not the native genotype. Recently, two genotypes, a native and a non-native strain, were identified and are present in marshes of the United States. The native strain is less invasive and has been present in Eastern tidal marshes for over 3,000 years (Kiviat and Hamilton, 2001). It is the non-native Eurasian strain that has colonized wetlands and displaced native marsh plants including the native *P. australis* strain (Saltonstall, 2002). If present, the native strain should be protected because it is an indigenous plant which has been a part of the North American plant community for thousands of years.

Currently, the GNN site still contains extensive areas of indigenous tidal marsh plants; however, stands of *P. australis* are now mixed with the native grasses and shrubs. The northeast corner of the GNN site is entirely overrun with *P. australis*. This section can be accessed by heavy equipment without damaging healthy salt marsh, so it will be regraded and replanted. Other sections of the GNN site, specifically along the eastern edge and at the southern reach, contain either small *P. australis* stands or do not permit the use of construction equipment and will be managed through the application of herbicide.

Except for a small strip of *S. alterniflora* adjacent to the creek and a narrow, wooded island, the PA site is entirely dominated by common reed. The majority of the site will be physically reshaped and replanted with native plants. A formal design for the site has been completed.

9.2.1.2 ***Salt Marsh Diversification*** - The goals proposed for the Mill Dam Creek (MDC) and Great Neck South (GNS) sites do not include the establishment of a *Spartina spp.* dominated salt marsh. Evidence could not be found to demonstrate that these two sites have supported a native tidal marsh plant community in the past. Aerial imagery produced in 1937 shows a palustrine forest present at MDC and GNS. More recent aerial photography depicts *P. australis*, not *S. alterniflora,* dominating the site. No information has been located to illustrate conditions at the sites between 1937 and the present.

In addition to not supporting a native marsh in the past, development adjacent to the two sites makes restoration goals developed for PA and GNN unattainable at GNS and MDC. Roads have been constructed along the seaward edge of each site and the wetlands are connected to the Lynnhaven system by relatively small culverts that severely limit the movement of water into and out of the marsh. This restriction of tidal flow produces environmental conditions that promote the growth of *Phragmites* (Roman et al., 1984; Montague et al., 1987; Chambers et al., 1999) because both salinity and soil sulfide concentrations are reduced once a salt marsh is impounded. *P. australis* prefers mesohaline marshes with salinities between zero and 18 parts per thousand (PPT), while saltwater with salinities greater than 18 PPT has been shown to stunt *P. australis* growth (Hellings and Gallagher, 1992; Lissner and Schierup 1997). *P. australis* growth is also impeded when soil sulfide concentration is greater than one mM (millimolar), a condition that is maintained when marsh soils are regularly flooded by seawater. Increasing tidal flow into GNS and MDC would be necessary to establish and maintain a *Spartina spp.* dominated marsh community and inhibit the growth of *P. australis*. Altering the culvert system was investigated as an alternative; however, the cost associated with replacing the culvert system was prohibitively expensive.

Monotypic stands of *P. australis* is not the optimal condition of a tidal marsh; however, *P. australis* dominated sites are not environmental wastelands as commonly believed. Recent scientific research has demonstrated that *P. australis* provides some environmental benefits and services, including the use by terrestrial and estuarine invertebrates and fish, erosion control, and nitrogen fixation (Faulds and Wakefield, 2003; Kiviat, 2006). While establishing a native salt marsh community would be the ideal goal, it is not realistic for the two diversification sites. Therefore, practical alternative restoration objectives and treatments were developed that would address site limitations and improve the ecological function of the current ecosystem.

As they mature, *P. australis* dominated marshes tend to become increasingly homogenous. The wetland plants trap sediment and dead vegetation, which results in decreased water depths, eventually filling in small creeks and pools on tidal marsh surfaces (Chambers et al., 1999; Weinstein and Balletto, 1999; Windham and Lathrop, 1999; Able et al., 2003). The elimination of tidal flushing also adds to the smoothing of microtopography within *P. australis* stands since silt is no longer removed from creeks through water movement. Reducing tidal flooding will also cause peat that makes up the creek banks to deteriorate, leading to sloughing of the creek banks. By building up the marsh surface, *P. australis* decreases habitat complexity, inhibits the movement of finfish into the marsh interior, reduces the interface between the marsh plain and the drainage system, reduces the number of edge habitats, and decreases the amount of nursery and feeding microhabitats, e.g. rivulets and inundated tidal plains, available to fish and other aquatic organisms (Weinstein and Balletto, 1999).

Ecological function will be improved at the GNS and MDC sites through habitat diversification. Habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous *P. australis* stands. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material. The material excavated from the tidal creeks and pools will be used to build upland mounds that will be planted with native shrubs or grasses. Although this strategy has not been employed in the

United States, a similar management strategy has been used successfully in England to increase habitat diversity and benefit wildlife, especially wading, passage, and wintering bird species.

As with the PA and GNN sites, plantings should take place between April and June. Some herbicide application may be necessary to kill *P. australis* rhizomes and foliage in the material used to create the upland mounds. Exclusion techniques will be used to protect the young plants from grazing by geese and other herbivores and best practices will be used to stop erosion and control sediment.

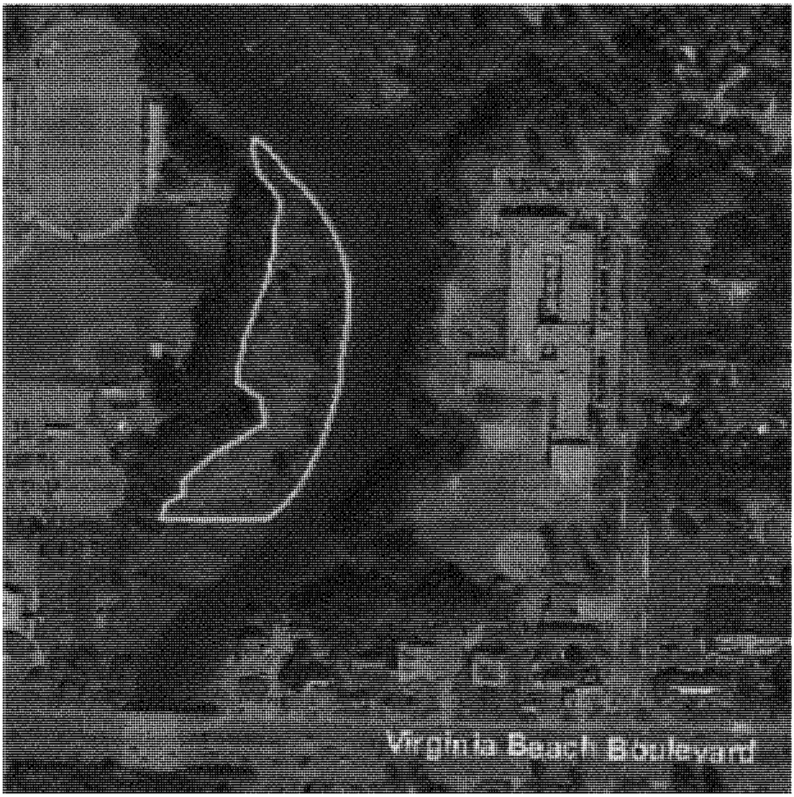
9.2.2 <u>Wetland Site Description</u>. Four sites within the Lynnhaven River Basin have been identified for restoration or diversification efforts in the Lynnhaven Restoration Project. Each site contains established stands for the nonnative, invasive, emergent plant *P. australis*.

9.2.2.1 ***Princess Anne Site*** - The PA site is half moon shaped with a fringe marsh and is approximately 3.82 acres in size (Figure 20). The site is located northeast of Virginia Beach Town Center, in a highly developed area of the city. The regions south and west of the site are highly urbanized, consisting of large, multistoried buildings and impervious surfaces such as parking lots and roadways. The areas situated to the north and east of the PA site are made up of residential neighborhoods of single family housing units.

The western edge of the PA site flanks Princess Anne High School and Thalia Lynn Baptist Church. A 50 to 100 foot wide forested buffer zone separates the marsh from the large parking lots, buildings, and recreational fields of the school and church. Thurston Branch runs along the eastern edge of the site. On the opposite shore across from the PA site, a single line of trees separates Thurston Branch from Thalia Elementary School. The school property is comprised of numerous buildings, a parking lot, and maintained lawn. A drainage channel separates the PA site from another fragment of salt marsh approximately one acre on the site's southern edge.

Thurston Branch runs along the entire eastern margin of the PA site, so tidal inundation is not restricted to the site. There is approximately 0.3 miles of shoreline composed of a thin band of tidal flats and native vegetation located along the site boundary. Immediately inland of the shoreline is a narrow, wooded, island that runs most of the length of the site. The area situated between the wooded island and the upland buffer, approximately three acres, is dominated entirely by *Phragmites austrialis*. The marsh running along the southern edge of the project site is vegetated with native salt marsh plants.

Figure 20. THE PRINCESS ANNE WETLAND RESTORATION SITE, VIRGINIA BEACH, VIRGINIA



9.2.2.2 ***Great Neck North Site*** – The GNN site is the largest wetland site included in the Lynnhaven Restoration Project, consisting of 19.98 acres of tidal marsh (Figure 21). The GNN site is a long, narrow salt meadow running north to south. It is approximately .33 miles in length and varies between .05 and 0.16 miles in width. The northern edge of the GNN site is defined by a bridge allowing Route 264/Virginia Beach Expressway to cross the channel which connects the marsh to Linkhorn Bay. Tidal flushing of the site is not restricted by the bridge. The southern limit of the site is established by Virginia Beach Boulevard. A Dominion Power right-of-way defines the entire western edge of the site. The upland beyond the right-of-way is made up of a narrow, forested border and the buildings, lawns, and paved parking lots of the two apartment complexes and self storage business that have been constructed adjacent to the site. The eastern side of the GNN site is developed with an apartment complex, a police academy, a trailer park, and a small number of single family houses. Most of the eastern edge has a narrow buffer zone separating the marsh from the developed upland. Beyond the buffer, the upland adjacent to the site is composed of maintained lawns, structures, and impervious surfaces.

The GNN site possesses a high level of diversity, both in vegetation and habitat types. Open water habitat is provided by the central channel that runs through the site from north to south and a single secondary channel that split off the main channel. The marsh has not been extensively ditched. A few bare pannes and dead standing trees can be found throughout GNN and tidal flats are located at the northern edge of the site. Wooded island habitat can be found in the northwest corner.

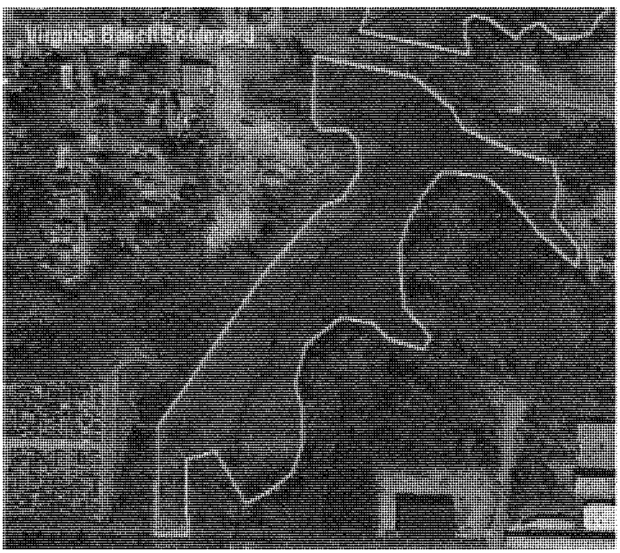
Figure 21. THE GREAT NECK NORTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA

A native salt marsh plant community including *Spartina* species and marsh shrubs is present at the site; however, the area also contains large stands of *Phragmites australis*. The northern and eastern quadrants of the GNN site are dominated by native plant species. *P. australis* fringes the main marsh and grows in large stands at drainage structures where freshwater enters the system. *P. australis* is starting to encroach on areas that are dominated by cordgrass and other native plants. The southern part of the GNN site is a mixture of native species and *P. australis*. However, larger amounts of the invasive common reed are present in this area than are found in the northern and eastern sections. The western quadrant of the site is made up almost entirely of *P. australis*, including the area west of the wooded islands that are located in the northwest corner of the site, the entire Dominion Power right-of-way, and the wetlands located to the west of the right-of-way.

9.2.2.3 ***Great Neck South Site*** – The GNS site is connected to GNN via two small culverts that run under Virginia Beach Boulevard (Figure 22). The culverts that link the sites restrict tidal flow between the two marshes. The GNS site is a large (13.68 acres), narrow salt meadow running from north to south. The site has similar dimensions as GNN and is about 0.32 miles in length and varies between 0.05 and 0.16 miles in width. The northern edge of the site is defined by Virginia Beach Boulevard and the southern edge is marked by a railroad trestle. The Dominion Power right-of-way present at the GNN site continues along the entire western edge of the GNS site. Beyond the right-of-way, the land adjacent to the western edge contains two large commercial properties, one of which is an auto salvage yard. This area consists of large parking lots, commercial buildings, wooded uplands, and a containment pool. The eastern edge of the GNS site contains two relatively large wooded areas, one approximately 7.5 acres in size and the other about 5.5 acres. Three commercial properties are also located in the eastern tract, including two self storage businesses. The area consists of wooded uplands, impervious surfaces, commercial buildings, maintained lawn, and about 1.5 acres of bare earth.

There is little diversity in habitat type and plant species at the GNS site. One central channel runs the length of the marsh from north to south. The marsh is not extensively ditched, but a few small drainage channels empty into the main central stream. Wetland shrubs grow along the central channel and a few bare pannes are located in the site. However, the majority of the site is vegetated with extremely dense stands of *P. australis*.

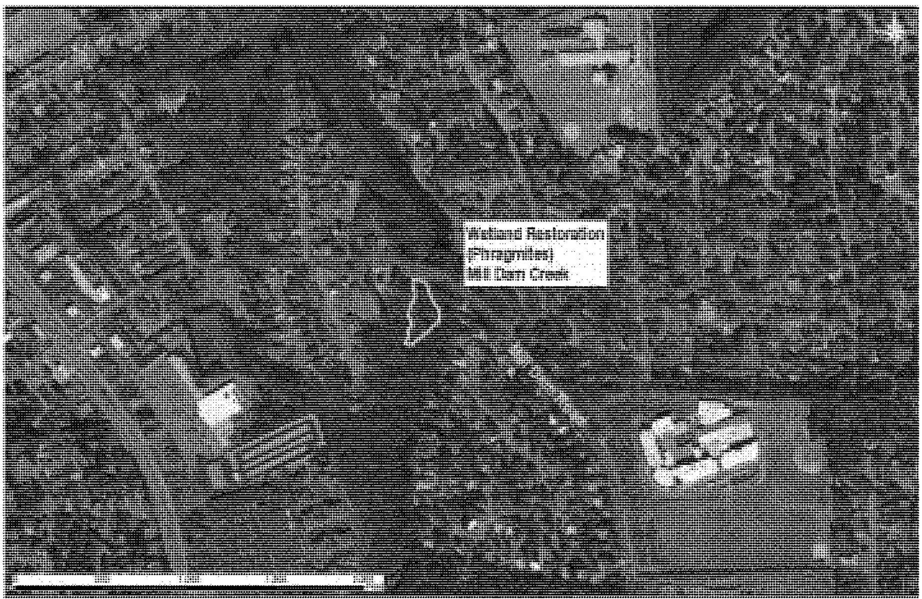
Figure 22. THE GREAT NECK SOUTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA



9.2.2.4 ***Mill Dam Creek Site*** **-** The wetland site with the smallest area is MDC site, which is approximately 0.9 acres in size (Figure 23). The site is a long, narrow marsh running from north to south. The northern edge of the site is delineated by Mill Dam Road. The southern edge of the site consists of wooded uplands. Both the eastern and western edges of the site abut residential property. The area surrounding the site consists of wooded upland, manicured lawns, single family houses, and roadways. Culverts that run under Mill Dam Road connect the site to Mill Dam Creek, which eventually empties into Broad Bay.

Tidal flow into the MDC site is severely restricted by the culverts. One central channel runs through the site and no ditching is evident. Other than shrubs that grow along the central channel and a few dead standing trees, the marsh is composed entirely of extremely dense *P. australis* stands.

Figure 23. THE MILL DAM CREEK WETLANDS SITE, VIRGINIA BEACH, VIRGINIA



9.2.3 Submerged Aquatic Vegetation. The 12 selected sites are in Broad Bay (42 acres) and the Lynnhaven Bay mainstem (52 acres). The sites will be planted with SAV seeds of two species, *Ruppia maritima,* widgeongrass and *Zostera marina,* eelgrass. Widgeongrass is a species that has a broader range of environmental tolerances than eelgrass and should be able to quickly colonize areas it is planted in. Seeds will be planted from small boats, likely Carolina skiffs, which are usable in shallow water. Seeds may also be planted using divers or mechanical planters operated off a small boat (ERDC/TN SAV-080-1 March 2008). Due to the greater environmental tolerances of widgeongrass, early efforts will be more focused on restoring it, though eelgrass will be attempted simultaneously in sites where it has the greatest chance for establishment. Once the widgeongrass is established, it should provide for more stable bottom and better water quality conditions that are conducive to the survival of eelgrass, which should then proliferate over a wider area. It is expected that the SAV beds established in the Lynnhaven River will be a mix of widgeongrass and eelgrass, with widgeongrass dominating. Monitoring will be done to determine the full extent of the SAV beds. The SAV will also be adaptively managed and reseeded if necessary.

Figure 24. SAV AND SCALLOP SITES – MAIN STEM

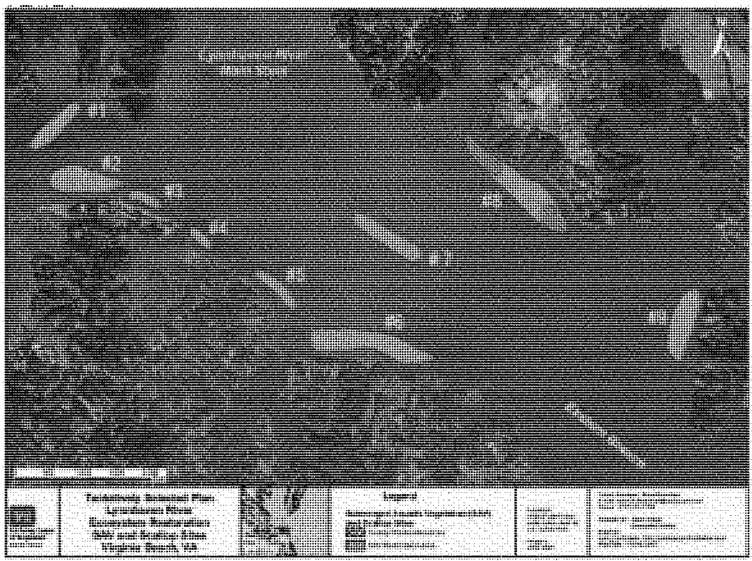
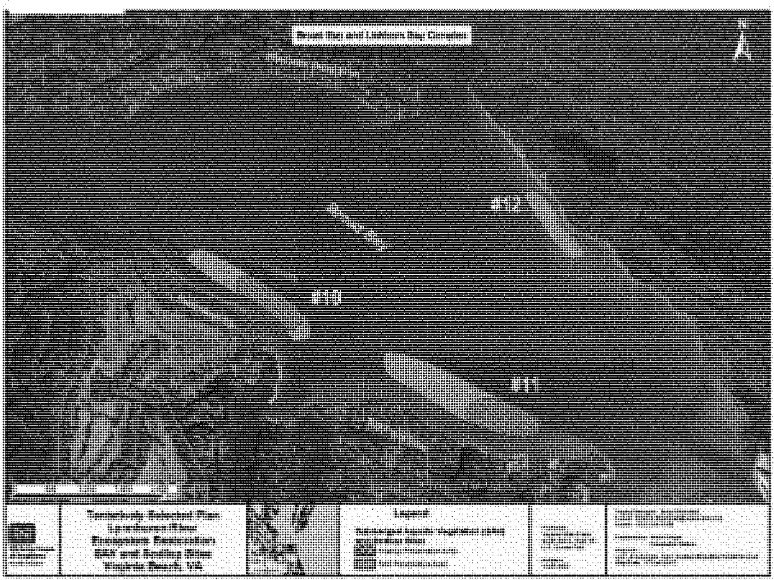


Figure 25. SAV AND SCALLOP SITES – BROAD BAY AND LINKHORN BAY



9.2.4 Reintroduction of Bay Scallops. The three sites selected for reintroduction of the bay scallop are located within the SAV restoration sites and total approximately 22 acres. The SAV beds would be restored first because Bay Scallops are known to prefer it to other substrates. No scallop restoration would commence until a minimum of one year after SAV restoration begins. While USACE expects scallops to colonize other substrates such as oyster reef habitat and macroalgae beds, particularly the red algae *Gracilaria vermiculophylla* (Falls, 2008), healthy SAV beds are required to establish a sustainable scallop population in the Lynnhaven River.

Two main techniques are used in restoring Bay Scallops; the direct stocking of juveniles or adults within SAV beds and the use of broodstock adults kept in cages at high densities to protect them from predators and aggregate them for increased spawning efficiency. A combination of both techniques, broodstock adults kept in cages to provide for maximum spawning efficiency as well as direct stocking of juveniles and adults into restored SAV beds would increase the chances for successful reintroduction of the bay scallop to the Lynnhaven River. For the broodstock technique, a minimum of 150,000 adults and an additional stocking of at least 300,000 juveniles is recommended. For the adults in cages technique, the cages are placed on the bottom at several locations. The preferred time of year for placement is from August through September. There are several types of cages and netting systems available. The SAV and bay scallop restoration sites are shown in Figures 24 and 25 above.

Scallop restoration in the Lynnhaven is in essence a reintroduction since there are no scallops in the River at present. The stocking of scallops in the river is a two part strategy. The first part is the introduction of adult spawners in racks and cages. Reproductively mature adults will be contained in racks at high density (≥ 100 scallops per square meter of river bottom) at several sites in the Lynnhaven River during the spawning season. Sites will be identified as source sites via hydrodynamic modeling and based on prior modeling, will be located primarily in Broad Bay. To document the success of spawning, plankton tows, settlement bags, and/or direct sampling for juveniles within SAV beds will be needed.

After spawning, surviving adults will be released within restored SAV beds, starting with the largest, most successful SAV beds, preferably within the source sites. Continued monitoring of adults and recruited juveniles will be needed to estimate the total population. Based on the population estimates, it may be necessary to repeat this several times and/or use more adults per spawning event until enough juveniles recruit for self-sustaining population development.

The second part is the direct stocking of juvenile scallops into SAV beds. Young juveniles (> 10 mm but < 25 mm) are proposed to be stocked within several of the restored SAV beds. This will function to immediately establish a population in the wild, help in the assessment of survival, and restore the ecological function of the scallop to the Lynnhaven in conjunction with the adults in spawner racks. The desired initial density of juveniles in stocked sites is 25 scallops per square meter of SAV bed. While direct stocking of restored SAV beds is an important part of scallop restoration, recruitment in them is preferable.

9.2.5 Reef Habitat. The nine sites selected for the construction of reef habitat are located in the Lynnhaven Bay mainstem and the Broad Bay/Linkhorn complex. The sites in the Lynnhaven total approximately 10.5 acres of low relief reefs utilizing hard reef structures with a density of approximately 2,000 hard reef structures per acre. The low relief hard reef structures are about two feet in height and three feet in width. The sites in the Broad Bay/Linkhorn complex total approximately 21 acres and consist of high relief hard reef structures with a density of 500 hard reef structures per acre. The hard reef structures range in size from four feet four inches in height and five and half feet in width up to five feet in height and six feet wide.

The bottom conditions are relatively firm sandy bottom for most of the selected sites. One site in Broad Bay has some soft bottom that would require the placement of rock filled mats on the bottom prior to the hard reef structures being placed on top in order to prevent subsidence. This site is approximately ten acres in size and is identified as site 8 on Figure 27. Figures 26 and 27 show the sites selected for reef habitat.

Figure 26. LYNNHAVEN BAY MAINSTEM REEF HABITAT SITES

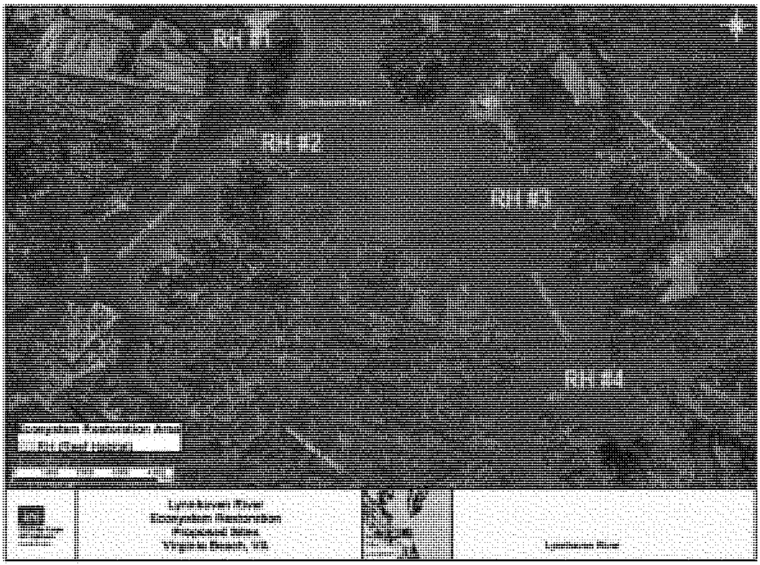
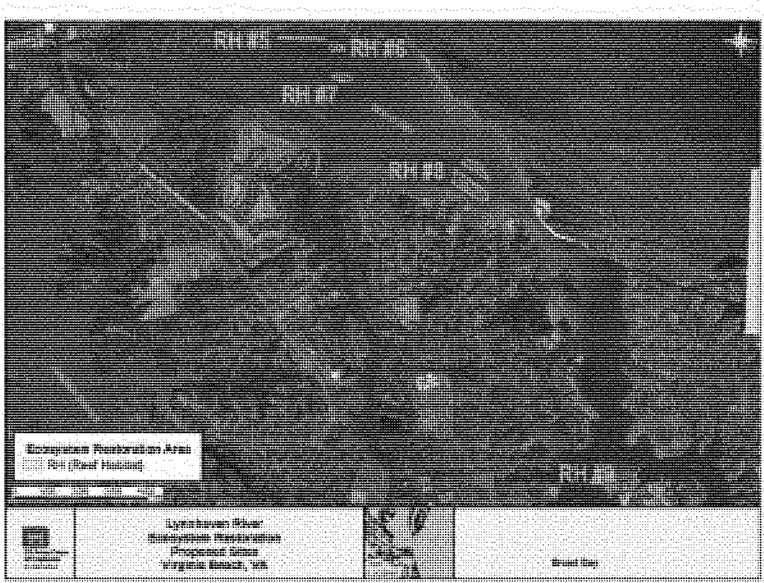


Figure 27. BROAD BAY AND LINKHORN BAY REEF HABITAT SITES



9.3 Real Estate Requirements

The SAV, Bay Scallop restoration, and Reef Habitat features will be constructed on river bottoms owned and managed by the Commonwealth of Virginia. The Non-Federal Sponsor will obtain any required permits, including a permit for work on state-owned river bottoms from the Virginia Marine Resources Commission. Some of the identified parcels for SAV, scallop, and reef habitat are currently leased by the Commonwealth of Virginia for purposes of oyster harvesting. The Commonwealth may grant a lease, easement, or other limited interest in state-owned bottomlands covered by waters as long as the property is used by a governmental entity for the performance of a governmental activity. The Non-Federal Sponsor will be responsible for acquiring or terminating these leases and for obtaining a non-standard perpetual easement over the river bottom required for the project. No Temporary Work Area Easements are anticipated to be required for these activities as all construction and access will take place from work boats in public access waterways.

The Wetlands Restoration feature will be constructed on land owned by the Non-Federal Sponsor and by private property owners. It is proposed that the Non-Federal Sponsor will obtain a non-standard wetlands easement in perpetuity over the wetlands restoration sites in order to provide perpetual protection of the Project. Temporary Work Area Easements, using the standard estate, will be obtained for construction, laydown and staging of construction materials and equipment needed to develop the wetland areas, and for access during construction. The Real Estate Plan that supports this report is located in Appendix E.

The real estate costs for this project are included in Table 19. The estimate of Lands, Easements, Rights-of-Way, Relocation, and Disposal Areas (LERRDs) incorporates all costs to acquire the necessary real estate including the federal government and non-Federal sponsor's administrative costs. A more detailed breakdown of the LERRDs cost can be found in the Real Estate Appendix.

9.4 Risk and Uncertainty

The placement of each element of the Lynnhaven Restoration Project has been carefully considered to ensure that current environmental conditions can support all measures included in the preferred alternative. However, due to the complexity of the natural environment, all risk and uncertainty cannot be eliminated from environmental restoration efforts. The risk and uncertainty of the Lynnhaven River Basin Restoration Study is given in Table 20 that is located at the end of the Risk and Uncertainty section.

9.4.1 <u>Submerged Aquatic Vegetation</u>. There is risk associated with the restoration of SAV in the Lynnhaven River considering the mixed results of SAV restoration efforts in the Chesapeake Bay (Moore, 2009; Erwin and Beck, 2007). A very small scale attempt was made in prior years to transplant adult SAV plants in the Lynnhaven River, which failed to persist. This is a not uncommon when transplanting adult plants (especially eelgrass, which was the species planted) and should not be used as a definitive indicator that SAV cannot survive in the Lynnhaven, especially since remnant patches of SAV currently persist in the river. Positive results have been observed near the Lynnhaven River where there has been a successful SAV restoration effort at the Little Creek Naval Amphibious Base, which lies immediately west of the Lynnhaven River. SAV restoration may fail because seeding will fail to establish SAV beds that persist longer than a season. Factors contributing to this may include cow nose ray foraging, boat propeller damage, storm events, or an adverse change in water quality.

Poor water quality, specifically high turbidity and TSS, is a possible risk factor associated with the SAV restoration. Water quality has improved since a significant SAV population was present in the Lynnhaven River; water clarity has increased, TSS has gone down, and eutrophication has decreased. Additionally, conditions at the Little Creek SAV restoration site are very similar in profile to that of the Lynnhaven River. Although the river is far from pristine, basic water quality parameters are suitable in the areas selected for the proposed SAV restoration. However, if water quality does not support the growth of SAV, the restoration will not occur and be postponed until water quality improves.

Schools of foraging cow-nose rays have the potential to inflict significant damage on newly restored SAV beds. Research conducted by the Norfolk District on oysters (Schulte, unpublished data) indicates that this species feeds on unprotected, loose oysters not embedded in a reef structure. Small schools of cow-nose rays have been documented in the Lynnhaven River. During the first years post seeding, SAV beds are not likely to hold large populations of adult oysters that cow-nose rays feed upon. This should lower cow-nose ray foraging within the beds and spare them from excessive damage. The chances of significant cow-nose ray related damage are low, but not insignificant.

The risks associated with SAV restoration will be mitigated through a number of strategies. Two species of SAV, the hardy pioneer species *Ruppia maritima* along with the more fragile eelgrass *(Zostera marina)* will be utilized through seeding instead of using adult plants. *Ruppia maritima*, also known as widgeon grass, has broader environmental tolerances than eelgrass. The creation and enforcement of "no wake" zones will also reduce the risk associated with SAV restoration by identifying areas that should be avoided by boater. Coordination with the local sponsor, the City of Virginia Beach, will be needed to create several additional "no wake" zones over some of the proposed SAV beds.

SAV beds that result from the initial seeding effort may not be able to persist more than a season even if all of the other risk factors have been eliminated. It is possible that the initial seeding may be too small to establish beds large enough to be self-sustaining. If the beds are not producing enough rhizomes and viable seeds to overwinter for until the next season, reseeding in the beds and possible additional seeding of nearby areas will be considered as an AM strategy.

9.4.2 <u>Reef Habitat</u>. Risk for this measure is relatively low overall. As long as appropriate bottom conditions exist, the placed artificial reef structures will quickly be heavily colonized by various sessile invertebrates. The Lynnhaven River system contains abundant planktonic larvae of many species during their reproductive season, from the spring through the fall. It is expected that these organisms will be fed upon by motile nekton, enhancing their abundance, biomass, and diversity. Reef dependent species, in particular, will utilize the new hard structure. Hard reef structures placed in shallow waters during various experiments with native oysters have demonstrated that artificial reefs can endure powerful storms such as nor'easters without being knocked over or buried. Hard reef structures were deployed in many areas of the Lynnhaven and have been heavily colonized by oysters, mussels, barnacles and other sessile organisms successfully in recent years. Of all the options being considered, this one has the lowest risk of failure.

Elements of water quality, specifically sedimentation and dissolved oxygen (DO), may affect the success of reef habitat. Water quality is sufficient for the restoration purposes of this project but are still not meeting all state water quality standards. Sedimentation can be a threat to the success of reef communities. As suspended material sinks to the ocean floor, it can smother animals fixed to the reef structure. Restoration sites were chosen in areas that do not experience high rates of sedimentation. Reef communities require specific levels of DO to thrive. The Lynnhaven River is a shallow, well-mixed, sub-estuary of the bay which is not prone to long-term hypoxia. The Lynnhaven is considered impaired due to DO concentration because of short term occurrences during the summer. Long term averages in the Lynnhaven River are well above five mg/l, the level which fully supports all estuarine life. Currently, the system supports 63 acres of sanctuary reefs and 2,047 acres of the river is open to harvesting shellfish, demonstrating that the Lynnhaven River can support reef habitat communities and other benthic organisms. Site selection was carried out using current water quality data and the footprint of historic oyster reef. Current water quality will support the proposed restoration efforts.

9.4.3 <u>Bay Scallop Restoration</u>. Of all options in the selected plan, the riskiest is scallop reestablishment. Scallop restoration cannot be attempted without prior significant and successful SAV restoration. These measures must be developed in sequence because the risk of failure will be too high to attempt scallop restoration unless SAV restoration meets the goals established in this report since scallops prefer SAV as their primary habitat.

Even with successful SAV restoration, there are other risks associated with scallop restoration. The proposed plan recommends stocking with larger numbers of scallops within a smaller habitat than prior successful efforts in North Carolina embayments. These embayments had the advantage of small populations of wild native scallops, which may have helped with recruitment, whereas in the Lynnhaven the recruitment of scallops will depend entirely upon the stocked population. As such, there is risk that the scallops will fail to produce enough recruits to sustain a population over time. This risk is not insignificant, and the AM plan reflects this and further large-scale stockings are part of the contingency if needed and if SAV beds are present.

Additional stocking is the chief corrective action recommended if the initial population collapses or fails to produce sufficient recruits. Stocking options include placing adults in cages as broodstock and direct stocking of adults and/or juveniles into SAV beds. Due to the inherent risk of this restoration option, it is recommended that a sizeable contingency be set aside for a large-scale restocking effort in the event that it is needed. Such a stocking event could be as large as the initial stocking effort, but that would only be necessary if the scallop population had collapsed. Experts from the scientific community will also be consulted to further refine the contingency plan prior to its implementation.

A population collapse is not likely, but could potentially occur during a hurricane or similar event, which could reduce the salinity of the Lynnhaven River enough to cause mass mortality. If some environmental event causes a die-off of the SAV beds, the scallop population might also collapse. Scallops can seek refuge in other habitat types, such as macroalgae beds, marsh edges, and oyster reefs present in the system. In this situation, enough individual scallops would survive with additional numbers added by volunteer scallop gardeners deploying spat collection bags to reestablish the scallop population once SAV beds recover within a few years. In the event of a freshet, scallops can endure such conditions for several days during cold weather, when such an event is more likely, but they still could be extirpated if the hurricane induced freshet persisted for more than a brief period. Due to the isolation of this population, any population collapse most likely will require restocking. However, if scallop restoration efforts currently being initiated on the lower Eastern Shore are successful and are providing recruits to the Lynnhaven River, then restocking may not be necessary.

Another potential threat to scallops would come from cow-nose rays. Cow-nose rays are primarily eaten by various shark species, so the depletion of the sharks has allowed the rays to increase in numbers. The diet of this ray species consists of crustaceans and mollusks. As a result, the increasing population of cow-nose rays has negatively impacted scallop populations on the East Coast of North America (Myers et al., 2007) and could also do so in the Lynnhaven. There are several corrective actions that could be taken in the event that cow-nose ray predation becomes a significant problem in restoration sites in the Lynnhaven. For example, small areas within the SAV beds could be protected using PVC stakes fixed with netting. This has been done successfully in Suitable Areas and could be used here to provide ray-free refuges to help maintain the scallop population. This would only need to be done in limited areas for a few months of the year to ensure reproductive success and would not be prohibitively expensive. Also, a fishery is currently in development for the cow-nose rays, which could reduce their numbers. Recreational fishermen could be encouraged to keep rather than catch and release cow-nose rays. Better management of shark fisheries would also be of assistance, but that is beyond the scope of this study or the purview of USACE.

Low DO concentrations in the water column are not a significant threat to the success of the scallop restoration measure. Scallops filter large quantities of water, but utilize only a small amount of oxygen available. In fact, it has been determined that the rate of oxygen uptake by Bay Scallops is independent of DO concentrations in the water column down to 1.5 ppm (Van Dam 1954). The DO target range that will allow the growth and reproduction of adult Bay Scallops is not less than 2 mg/L for less than two hours (Leverone 1993). The areas identified for restoration have higher levels of DO, so water quality will not limit the success of bay scallop reintroduction to the Lynnhaven River.

The risk associated with Bay Scallops will be mitigated with the successful restoration of SAV and the scale and diversity among the sites selected. Additionally, a thirty percent contingency has been added to the construction costs for Bay Scallops to account for any reseeding that may be needed.

9.4.4 Wetlands Restoration/Diversification. The selected plan incorporates two treatments that will be employed at the four wetland sites. The first, restoration, includes the removal of *Phragmites australis*, common reed, from the site in order to restore components of a *Spartina sp.* dominated marsh. At sites where the complete removal of common reed is not a practical alternative, a second strategy, diversification, involving the increase of habitat diversity through the construction of habitat features, will be employed.

Due to the heartiness of *P. australis*, it is extremely difficult to eradicate this species completely from an area. There is a risk that the project efforts will ultimately fail and the invasive species will not be entirely removed from the restoration sites. The Recommended Plan includes the excavation of plant material and sediment from each restoration site in order to lower the elevation of the marsh and to remove all *P. australis* material from the area. *P. australis* creates extensive root mats which, if not completely eliminated, will sprout and allow continued growth. Additionally, adjacent populations supply rhizomes and seeds that can propagate in the project area, even if all of the on-site *P. australis* material is removed during the original construction effort.

Risk will be minimized by altering the marsh hydrology and elevation to favor a native marsh plant species. This will be done by lowering the elevation of the marsh surface and creating tidal channels, which will increase the area that is regularly inundated by the tides. Common reed is less tolerant of salt water and inundation than the native plants. Another project element designed to stop the reintroduction of common reed, which is also included in the AM plan, is the application of herbicide. A chemical appropriate for use in and around water will be applied to existing *P. australis* stands. For ten years after the completion of the Lynnhaven Project, each site will be monitored for the return of common reed and herbicide will be used as needed.

Another uncertainty associated with the restoration efforts is the success of the native plantings. Young marsh plants are easily damaged. Examples of disturbances which could increase plant mortality include grazing by geese and other herbivores, large weather events, and human trampling and vandalizing. Although no management actions can be implemented to reduce the impact of some risks, such as storms, actions can be taken to reduce the risk of other elements. For example, fencing and overhead wires can be installed to prevent geese from grazing at the site. The goose exclusion structures can perform a dual purpose by also limiting the access of people to the site. Signs can also be placed at the site to inform people to stay out of the area.

The risk associated with the diversification sites is that habitat features created during the original construction phase will be filled in by *P. australis*, ultimately reducing habitat diversity. The Recommended Plan entails the construction of features such as open, shallow pools and wide, tidal creeks that are not currently present. The effect of common reed on marsh habitat is to fill in microhabitats, ultimately smoothing the marsh surface. Some elements will naturally withstand the colonization of *P. australis*. *Phragmites* is less able to withstand the inundation of tidal waters. Currently at the diversification sites, native shrubs line the existing tidal creeks. The newly constructed creeks should also favor the growth of native plants, which will stabilize the banks. The AM plan also includes monitoring of the habitat structures for re-establishment of *P. australis* and the application of herbicide as needed. The plan also allows for the repair of habitat features every five years.

A final risk related to the wetland measures is the possibility of finding contaminated soils at the proposed sites. The material that will be disturbed falls into two categories: (1) the material that is reused for beneficial purposes at the diversification sites and (2) the material that will be removed from the wetlands and replaced with clean fill in order to eliminate the invasive plant species. A tier 1 analysis, as described by the Clean Water Act, will be performed to characterize the material and ensure that contaminants are not released into the system. For the material that will be removed from the restoration sites, the sediment will be tested for contamination prior to construction as required for all material sent to a landfill. BMP's will also be taken to ensure sediment does not enter the water column. BMP's will be incorporated not only to keep any existing contaminants from being released; they will also ensure that the project does not contribute to TSS levels in the Lynnhaven River.

9.4.5 <u>Sea Level Change.</u>

9.4.5.1 ***General*** - Prevailing climate science predicts continued SLC in the future as the global climate warms. This change in ocean height is expected to result in increased coastal erosion, salt water inundation, flooding, and storm surges which will significantly impact coastal regions of the United States. In order to address future environmental conditions, USACE recently issued EC 1165-2-212, "Sea-Level Change Considerations in Civil Works Programs" requiring that the direct and indirect physical effects of SLC be assessed during all phases of USACE civil works projects. The USACE guidance document provides three different accelerating eustatic SLC scenarios. The most conservative scenario incorporates the historic rate of relative sea-level change. The intermediate and high scenarios are curves introduced in the Natural Research Council (NRC) report "Responding to changes in sea level: Engineering implications" (1987) as described in Chapter 12.12.

9.4.5.2 ***Wetlands*** - Tidal marshes are dynamic places which, to a point, can adapt to changing environmental conditions. Two mechanisms, vertical accretions and marsh transgression, allow marsh plants to adjust to increasing sea level. By building vertically through the accumulation of sediments and plant organic matter (plant roots etc.), marshes can keep pace with local ocean level rise. Reed (1995) suggested that wetlands can adjust to a maximum SLC of 0.12 in/year; but if sea level increases at a greater rate, wetlands will erode or be converted to tidal mud flats or open water (Cahoon et al., 2009). The Lynnhaven system has historically experienced an annual sea level rise of approximately 0.17 in, yet historic maps and aerial photography suggest that the marshes within the Basin have continued to sustain themselves (Berman and Berquist, 2009).

Wetland habitat can also adjust to SLC through "marsh transgression," with marsh plants migrating landward into new areas as terrestrial habitat becomes inundated with saltwater. However, shoreline development and associated structures (e.g. erosion control structures, roads, or bulkheads) can impede the migration of wetlands. The Lynnhaven Basin includes 266.6 miles of shoreline, with approximately half (127.4 miles) associated tidal wetlands. Eighty-five percent of those marshes (108.1 miles) exist in conjunction with development, which elevates the risk to survival for those wetlands as sea level rises (Berman and Berquist, 2009).

9.4.5.3 *SAV* - The marine grasses that make up SAV beds require relative high water quality and have narrow tolerances for salinity, light, temperature, nutrient levels, and sediment type. Global climate change and the associated SLC will influence the conditions experienced in the shallow tidal zone where SAV habitat is located and may negatively impact SAV beds. Annual rainfall is expected to rise, increasing runoff into the system. Larger amounts of runoff usually result in higher levels of sediment in the water column which, in turn, increases turbidity and decreases light transmission. Runoff also carries nutrients into the ocean. Nutrients enhance phytoplankton growth in the water column and epiphytic growth on the leaves of submerged plants. Both of these conditions limit the amount of light reaching SAV.

The frequency of high intensity storms is also predicted to increase. The storm surges and wave action associated with these storms could result in more coastal erosion and damage to SAV beds. Increased atmospheric temperatures from climate change would also result in higher oceanic temperatures, especially higher average summer temperatures. Eelgrass, the dominant SAV species in the Chesapeake Bay, is very sensitive to changes in water temperature and small increases in temperature could result in large population losses of eelgrass (Moore and Orth, 2008). Other species, such as

Ruppia maritima, which is included in the selected restoration plan, are more environmentally tolerant. Species composition of seagrasses as well as motile fauna may also change as species with a more southern distribution migrate northward as oceans continue to warm (Fodrie et al., 2010; Micheli et al., 2008; Short and Neckles, 1999).

9.4.5.4 ***Bay Scallop Restoration*** - Atlantic Bay Scallops are associated with sandy, reef, macroalgal, and muddy substrate was well as SAV beds. Although the current study did not assess the populations of scallops that will likely be found in these non-SAV habitat types, considerable numbers could be found in these areas as a result of successful scallop re-introduction. As SAV beds adjust to environmental conditions, the scallops will move with the submerged beds. If SAV beds do not flourish in the Lynnhaven system, the scallops could persist in other habitat types, though likely in smaller numbers if seagrasses decline.

Table 20. SUMMARY OF PROJECT RISK AND UNCERTAINTY

Item	Recommended Plan	No Action
Risk of Failure (Risk that the project will not provide stated benefits)	**Reef Habitat** – Low, risk of sinking into sediment, displacement by storm events, and sedimentation **Wetlands** – Moderate, re-colonization by exotic species at eradication sites or overgrowth of constructed habitat features by exotic species. **SAV** – Moderate, failure of seeding as a result of adverse water quality, cow nose ray foraging, boat propeller damage, storm events, or failure to establish persistent beds. **Scallops** – High, Dependent on and will only proceed with the success of SAV restoration. Risk of producing a sustainable population, predation by cow nose ray, or population collapse due to environmental event.	N/A
Residual Risk (Risk to structures and population once plan is implemented)	No effect	No effect
Risk from Accelerated Sea Level Change	Depending on the rate of SLC, SAV and salt marsh will migrate into newly inundated areas. If SLC is too high or the shoreline is developed, SAV and salt marsh will be lost. Plant community associated with reef habitat may change as sea level increase due to increase light attenuation.	Depending on the rate of SLC, SAV and salt marsh will migrate into newly inundated areas. But predict loss of wetlands within the Lynnhaven Basin.

9.4.6 <u>Sensitivity Analysis on Uncertainty of Project Cost and Risk of Project Success</u>. Risk and uncertainty were considered throughout the entire process of plan formulation and evaluation of the alternative plans. However, a sensitivity analysis was conducted on the results of the CE/ICA to account for any risk and uncertainty that could not be accounted for through the design of the projects or the estimation of the project benefits. The purpose of this sensitivity analysis is to validate the recommendation of the NER Plan with consideration of the uncertainty of project costs and the risk of project success. More detailed information on this sensitivity analysis can be found in the Economics Appendix.

The risk associated with success of the SAV component of the project is the highest. Scallops were considered to have a relatively high risk as well, due to their dependency on SAV as well as their own establishment. Therefore, CE/ICA was conducted with the costs for the SAV/scallop measures increased by 50 percent and again with costs increased by 100 percent. There was no effect on the outcome of the best buy plans identified to be carried forward for consideration with a 50 percent or 100 percent cost increase on the SAV/scallop measures.

It is recognized that there is a risk associated with construction of the Essential Fish Habitat. Therefore, CE/ICA was run with the costs for this measure increased by 50 percent to account for this risk. With a 50 percent increase in reef habitat costs, there was no change to the plans identified as best buy plans by the analysis.

A sensitivity analysis was also conducted on the separate wetland analysis. There is inherent risk associated with the success of growing native species in place of invasive species. To account for this, CE/ICA was rerun with a 25 percent cost increase applied to the Great Neck North and Princess Anne High School sites. This resulted in different incremental costs per output but no change in the best buy plans identified by the analysis.

9.5 Monitoring and Adaptive Management

9.5.1 Monitoring. The aquatic systems which this study aims to improve are dynamic and complicated. It is unlikely that restoration objectives would be achieved if the proposed measures were simply constructed without further monitoring. All monitoring described in the following section should be completed by specialists with the subject matter expertise necessary to design and conduct the monitoring. These will likely be scientists from regional universities with published work and research relevant to the restoration effort.

9.5.1.1 ***Reef Habitat Monitoring*** **-** The fish reefs will need to be assessed annually for up to 10 years post placement to determine the health of the sessile benthic community that grows upon them and also to determine nekton usage. The first five years will likely be annual, and if the reefs appear to be on track to reach desired secondary production levels, bi-or tri-ennial monitoring can begin. Such surveys could include direct monitoring by divers on the reefs and taking samples on and around the base of the reefs in order to determine the species composition, biomass, and growth rates of the biota on the reefs. This might also be performed by raising a small number of reef structures to the surface for sampling, along with benthic bottom grabs near the reef base. Further actions could include use of a remotely operated underwater vehicle (ROV) or stationary cameras to take video to document fish use in and around the reefs, as well as to examine the reefs themselves. Such a technique is less invasive than direct sampling. Random sampling on a small sub-set of reef structures at each proposed reef site will be necessary for a complete monitoring program. Sufficient samples will be taken to keep the SE (standard error) within 25% of the mean (average) value.

For oyster reef restoration projects, which these reefs are similar to, this will require approximately 30-60 samples from the entire reef complex which includes all sites and types of structures throughout the river (not 30-60 per reef site). This should ensure sufficient statistical confidence in the results to clearly see trends in indicators to allow for proper documentation of project objectives and goals, as well as to decide whether or not to implement any adaptive management measures. The main management trigger point is secondary production, which is annualized for the reefs. The following table shows the expected values over time. Failure to meet at a minimum 50% of the desired number of these annual metrics will require re-visiting the project implementation schedule and construction plan, as well as possible the goals and expectations for the project. The need to conduct additional research to attempt to determine why goals are not being met will also be considered. Such information could result in modifications of subsequent deployments.

Table 21. Reef Secondary Production Over Time

Reef Secondary Production Over Time, High and (Low) Relief Reef	
Year	Secondary Production (kg/acre/year) for high and low (in parenthesis) reef habitat
0*	223 (180)
1	446 (360)
2	891 (720)
3	1783 (1440)
4	2897 (2341)
5	4457 (3601)

*assumes deployment prior to first settling season no later than April with first monitoring results for year 0 obtained from a fall survey. If deployment is later year 0 should be moved to one year later.

Other indicators that should be documented are the presence of reef-dependent fish utilizing the reef structures as well as the species composition of the sessile and motile organisms living on the reef structures, which can be used to estimate increases in BIBI from the pre-construction conditions. While the species composition can be calculated during the physical sampling of the reefs, the reef fish assessment is recommended to be done using underwater video. If such species are not observed, credit for their secondary production should be re-assessed (Peterson et al. 2003) and downgraded, as it is part of the goal metric secondary production. Small reef dependent species such as gobies, blennies, toadfish and clingfish should be observable on the reef. Larger structure using species, such as black sea bass, sheepshead, tautog, gag grouper, spottail pinfish, silversides, sheepshead minnow, pigfish, cobia, black drum, and others should also be observed utilizing the constructed reef habitat. From the video, record should be made of fish species observed and approximations of their numbers. If this proves insufficient, fish traps or other means to obtain physical samples should be considered. The other major component of the enhanced secondary production is an expected increase in blue crab and other crustacean production. Fishing records for blue crabs can be consulted to see if there is an increase in the area of the reefs, or if fishery independent data is desired, a separate study could be undertaken to assess blue crab density within the reef areas by comparing them to a sandy bottom open area without such structure.

Extensive monitoring at this level would be needed for the first five-ten years post construction. Ten years is needed for this option due to the large number of reef structures and the need to collect sufficient samples over a longer period of time than other options. The proposed reefs will likely take longer to mature than five years as a variety of species that use the reefs have longer life cycles, such as many of the larger reef-dependent fish species. Additionally, it is important to determine how long oysters and other shellfish survive on the reefs. In the past, oysters could live for up to 25 years and given the documented disease resistance of the Lynnhaven oyster population, a lifespan greater than five years may now be possible and it is important to document this. After that, assuming the reefs have matured, a smaller effort, primarily using a ROV, could be implemented at a lower cost and done once every 2-3 years. This effort would be supported by the local sponsor, as after the initial 10 years the USACE will close out the project and all monitoring (including the fish reefs, wetlands, SAV and scallops) will be the responsibility of the local sponsor, the City of Virginia Beach. Monitoring will be done by specialists with the subject matter expertise necessary to design and conduct the monitoring. These will likely be scientists from regional universities with published work and research relevant to the restoration effort.

9.5.1.2 ***Submerged Aquatic Vegetation Monitoring*** **-** The SAV beds will need monitoring to assure long-term persistence and to measure any expansion or changes in density of the SAV over time. The monitoring program for SAV should include an annual survey to assess the extent, density, and productivity of the beds for five-ten years post construction. A water quality monitoring program is already in place and data collected from it will also be consulted, as SAV persistence is dependent on good water quality. In the Lynnhaven, the minimums for the more fragile SAV species, eelgrass, are 15% light penetration at 0.5 m depth, < 15 ug/l ChlA, < 0.15 DIN (mg/l) and <0.02 DIP (mg/l). Widgeongrass is considerably more tolerant of lesser water quality and should be easier to establish.

It is important to note that these parameters are, on average, met in the areas of the Lynnhaven selected for restoration. SAV beds mature quickly, as do their associated benthic communities, and five years should be sufficient for the beds to mature and the benefits to match that of SAV beds located in small bays along Virginia's lower Eastern Shore. However, since the strategy focuses (especially at first) on a somewhat less persistent species, Ruppia, newly established SAV beds will need to be monitored for stability longer than the time needed to initially establish them, which may take only a year or two. After the first five year period, if the SAV beds are persistent, monitoring could be relegated to the annual monitoring program conducted by Virginia Institute of Marine Science (VIMS) that encompasses the entire Chesapeake Bay and includes the Lynnhaven River system. If not, it is recommended that the more extensive monitoring continue to be done for another five years for 10 years total monitoring. For the initial five year period, however, it is important to establish a more comprehensive monitoring program. Such a program would involve random samples within restored SAV beds, to determine both the health of the SAV as well as secondary production within the beds. Water quality data is already being collected by other agencies, though data on water currents may need to be collected in addition to this and such work would likely be funded under the present study's proposed plan.

9.5.1.3 ***Bay Scallop Monitoring*** **-** Scallop populations will need to be assessed in habitat they can colonize, which consists of SAV beds, gracilaria (macroalgae) beds, and oyster reef habitat. Monitoring can follow standard protocols for assessing scallops, which include counting them along transects or assessing their numbers in discrete sampled areas. Recruitment outside the restoration areas can be measured by "spat bags," which are loose bags of dense nylon nettings that scallop juveniles will set upon and grow. If the scallops recruit successfully, they should establish a self-sustaining population quickly, within five years of initial stocking. Monitoring should be more extensive during the first five-ten years, as this is the critical time for population establishment and deciding whether or not to implement various measures within the adaptive management plan. Monitoring costs for an annual scallop survey of juveniles and adults and an associated spat bag survey to assess abundance, dispersal, and recruitment, should be expected annually for the five year period. After this, a smaller scale survey could be implemented to ensure the scallop population remains viable. If the goals are not reached, however, the more extensive monitoring should remain in place for another five years while the adaptive management plan is implemented.

9.5.1.4 ***Wetland Restoration and Diversification Monitoring*** **-** The four wetland sites will be monitored twice annually. The monitoring efforts will be completed by either a USACE employee with a background in wetland function and plant identification or a contractor with a similar background. The results of monitoring efforts, whether they are completed by USACE staff or a qualified contractor, will be recorded and presented to the USACE within 30 days after monitoring has been completed to allow for the planning of adaptive management measures. The USACE, Norfolk District will maintain the monitoring data.

Restoration Sites The project objectives for the Princess Anne (PA) and the Great Neck North (GNN) sites include the restoration of the indigenous salt marsh community and reduction of the invasive plant species, Phragmites australis, present on-site. The key parameters that will be monitored at these sites during the adaptive management phase will include:

1. The presence of Phragmites australis in the restoration site,
2. Success of native plantings,
3. Integrity of habitat features (streams, pools, islands, etc.).

These three parameters are directly related to the achievement of an indigenous community and eradication of the exotic species.

The presence of P. australis must be monitored regularly for two reasons. First, the eradication of this invasive is rarely accomplished in one season. Instead, an infestation of P. australis is eliminated in small increments over a series of years. Second, if any P. australis remains at a site, the plant will continue to spread and replace the native plants. The monitoring of P. australis will be considered successful and complete once none is found on site.

Monitoring the native plantings will be necessary to fulfill contractual obligations and to ensure the success of the project. The planting contract will stipulate that the contractor must replace plants if a certain percentage (15% typically) fail during the first year. Later, plant success was be monitored to ensure that the design of the project was correct. For example, native marsh plants will succeed in a narrow elevation range. Even if the design is correct, there are many hazards that could interfere with the success of the native plantings. The native plantings will be considered successful if 85% of the planted areas are covered with native marsh grasses.

The final element of the monitoring plan will be assessing the constructed habitat features. Each feature will be observed to determine if it is structurally sound and functioning as intended. For example, tidal creeks and streams will be observed to make sure they have not become occluded and no longer allow the full tidal inundation. The upland mounts will be monitored to see if they remain at an elevation that supports upland plants and have those upland plants are not overrun by P. australis. This element of the project will be considered successful if the integrity of each habitat remained sound for three years and 85% of the upland island areas are covered with native plants.

Diversification Sites The "restoration" goals proposed for the Mill Dam Creek (MDC) and Great Neck South (GNS) sites do not include the establishment of a Spartina spp. dominated salt marsh. Instead, the ecological function of the two sites will be improved through habitat "diversification," specifically habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous P. australis stands. The key parameters during the AM phase to be measured at the sites where diversification has been implemented will include:

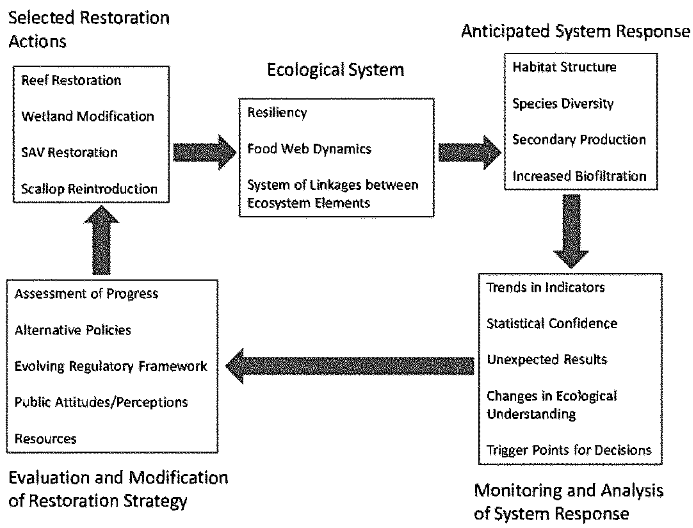
1. The presence of Phragmites australis in the constructed features that would impede the growth of native shrub plantings and would fill in tidal streams and pool,
2. Success of native plantings,
3. Integrity of features (streams, pools, islands, etc.).
4. Estimation of Secondary Production

The four parameters to be measured during monitoring ensure that the habitat features which have been created during the construction phase of the project remain viable. The monitoring activities and success criteria are described in the previous paragraphs. The maximum number of years (10) of monitoring is recommended for the wetland sites because the elimination of phragmites has been shown to be an ongoing process that requires many years of monitoring and removal efforts to be successful. Each cost estimate accounts for monitoring efforts required for the maximum acreage of each measure. For alternative plans with fewer sites, and thus less acreage, the monitoring amount was reduced accordingly.

9.5.2 <u>Adaptive Management</u>. Adaptive management (AM) is a structured, iterative process designed to learn from the lessons of the past in order to improve the chance of project success. AM costs are included in the construction costs for each of the alternatives. The AM costs are cost-shared just as the construction costs during the first ten years of the project. After the first ten years, all monitoring and maintenance costs are the responsibility of the non-Federal sponsor. The AM costs for each of the measures are estimated at ten percent of total project costs based on the following.

In order to adequately address the uncertainties inherent in a large environmental project and to improve the performance of the project, AM has been developed and adopted by the USACE. AM replaces dependency on numerical models and traditional planning guidelines which were used in the past to manage the unpredictability of complex environmental projects and, instead, applies a focused “learning-by-doing” approach to decision-making. The “learning-by-doing” approach is proactive – it is an iterative and deliberate process using the principles of scientific investigation. Through a program of regular monitoring that allows a better understanding of the ecosystem and the projects place in the system, a project’s design and operation are continuously refined. Information that can guide a project adaptive management plan (AMP) can include results from scientific research and monitoring, new or updated modeling information, and input from managers and the public. Potential applications of this “learning by doing” AM approach include: (1) transfer of lessons learned from one program/project to another to avoid pitfalls; (2) use of physical models/modeling to test possible outcomes of management decisions; and (3) incorporation of flexibility and versatility into project design and implementation. The basic process works as follows:

Figure 28. ADAPTIVE MANAGEMENT PROCESS



This AMP describes how the project elements of the Lynnhaven Restoration Project will be monitored and adjusted if long term monitoring finds adverse impacts on the native populations or if the project elements are not providing the benefits predicted in the integrated report. It describes the process for evaluating the results of the monitoring program, "triggers" or action points that would necessitate modifications to the project, and potential changes that would be implemented to improve the performance of the project. The monitoring program should accomplish the following:

- It should support adaptive management decisions by providing data on critical stages in the development of the reefs, scallops, SAV and wetlands that can guide the next steps in the restoration process. This monitoring should answer crucial questions that affect implementation decisions. For example: Did sufficient numbers of transplanted scallops survive and spawn to support continued stock development? Is the biomass on the reefs increasing? Are reef-dependent fish utilizing the reefs? Are the diversified wetlands maintaining the native vegetation along the re-graded contours or is it being re-invaded by Phragmites?

- It should evaluate intermediate conditions that help to track progress toward the final goals. For instance, are enhanced abundances of scallop larvae and new recruits observed in a tributary following seeding with broodstock? Are newly-seeded SAV beds increasing in shoot density per unit area of SAV bed annually? Is biomass increasing on the reefs on an annual basis as predicted? Such a monitoring objective permits setting intermediate goals and evaluating success in reaching those goals.

- It should measure specific elements necessary to evaluate success criteria established for the project. For instance, numbers and sizes of oysters and other sessile filter feeders are needed to evaluate the secondary production and filtration capacity of a restored multiple-use reef as proposed in the plan.

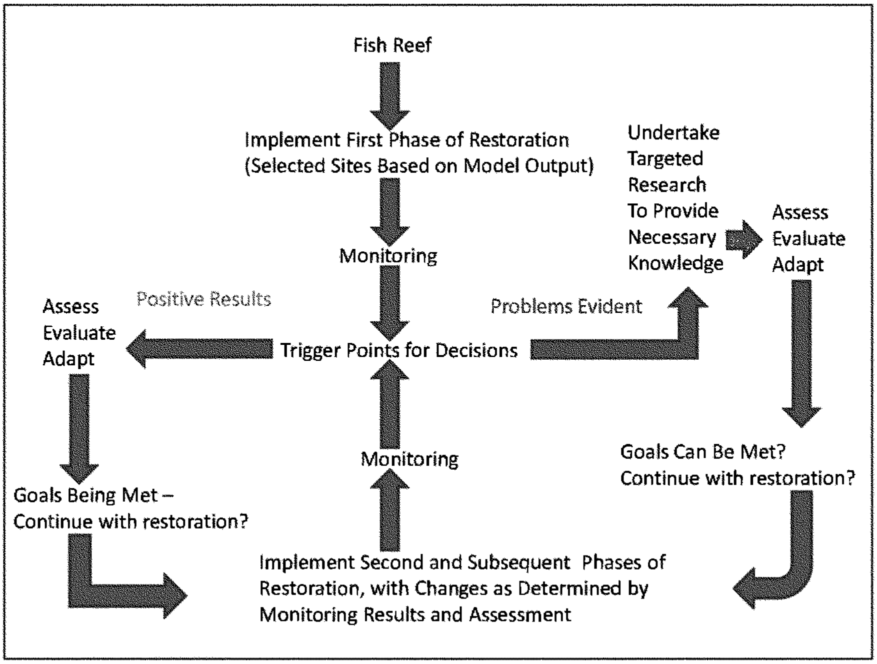
- It should aid in identifying unexpected stresses, environmental conditions, and/or ecological interactions that can affect the overall success of the project. For instance, water quality, particularly temperature, TSS and chlA, can be affected by a very wide range of factors; measuring all of which would be impractical, but having a monitoring program in place that could recognize when water quality problems affected the success of a project would be invaluable. Major storm events during periods where there are planktonic larvae of sessile filter feeders can significantly and negatively influence subsequent recruitment, which will result in lower than desired secondary production by the reefs. Droughts, on the other hand, can produce better conditions for recruitment.

As discussed in the risk analysis section, the risk varies with each project element, with scallop restoration having the highest risk, SAV moderate risk, and the fish reefs and wetlands diversification the lowest risk.

9.5.3 <u>Reef Habitat</u>. Once placed, fish reefs should need little intervention due to their durability. Due to the size of the project, though, there are opportunities to employ

AM as the project will be phased in over a period of several years. The numbers of reef structures necessary will take several deployments prior to the settling season (spring-summer) of local sessile and reef-dependent species. Several types of structures should be placed, as current available research does not identify which one is best for local use. The basic reef AM process is as follows:

Figure 29. ADAPTIVE MANAGEMENT PROCESS FOR REEF HABITAT



The first sites implemented will be based on prior model output and were identified as important source-sink areas for recruitment of oysters and other sessile life-forms that have a planktonic phase (Lipcius et al. 2008), with potential smaller-scale deployments in other areas if the leases are obtained and the bottom freed for use for the fish reefs.

9.5.3.1 ***Reef Habitat Adaptive Management*** **-** Due to the size and scope of the proposed reef habitat, the structures will be placed over a period of several years, which provides opportunity to make adjustments based on lessons learned. The first placements are proposed in areas determined (Lipcius et al. 2008) to be highly likely to recruit sufficient sessile invertebrates, particularly oysters, to meet secondary production metrics. Also, several different types of reef structures will be deployed, so we can collect data on which structures are best in the Lynnhaven and for different uses, such as shallow nearshore vs. deep water subtidal deployment. Fish, which are highly motile, will be attracted the reefs wherever they are placed, since the sites selected all have appropriate salinity regimes for the various reef-utilizing species.

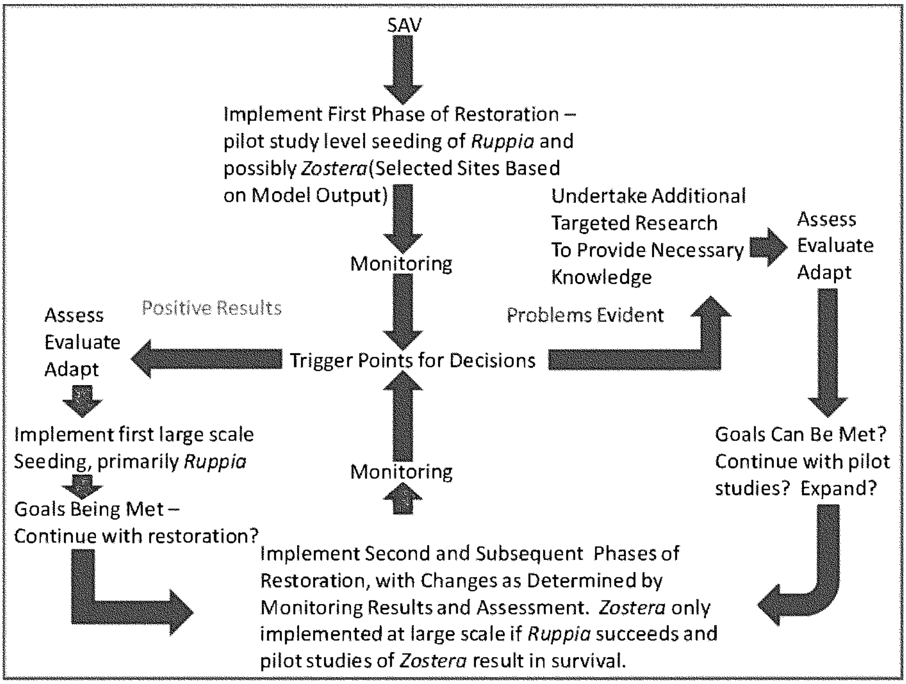
Based on the initial results, future reef placement will be considered and possibly modified in order to improve performance. Modifications could also include changing the shape, conformation and/or placement grid of the structures to improve performance as well as selecting alternative areas for placement. An additional measure would be to modify the design of the individual reef structures, as their shape can affect the surface area that is fully exposed to predation as well as sheltered internal areas not so exposed. Conformation changes could include changes in the concrete and stone mix to be more attractive to sessile larva for settlement or to enhance surface rugosity to provide for increased shelter for small post-settlement reef organisms. Extant reef structure, if failing to meet metrics, will also be considered for AM actions, of which there are primarily two: cleaning or moving to another location. However, before any AM action on placed structures is considered, all possible reasons for not meeting expected metrics should be considered as it is likely better to simply wait and give the reef habitat more time to produce expected benefits. Storms during times of recruitment, Bay-wide poor water quality (anoxia, high temperatures due to regional heat wave) can significantly lower recruitment and natural impacts to the reefs need to be considered prior to AM action other than waiting. Although there are other possible options available for improving the productivity of placed reef structures, two are described presently. If the reef structures become covered with sediment, divers could be hired to clean off the reef structures, or possibly a small dredge could be run in reverse, blowing off the sediments from the reef structures. This is not an expected maintenance event, and will only be done in the event a major storm results causes high enough sedimentation on the reefs that it overcomes the oysters' and other filter feeders' abilities to clear the reefs of the sediment. This clearance can take several months, so this action will not be triggered until at least a season of biological activity occurs post-storm on the reefs. A storm during the winter that deposits significant sediment on the reefs will not be removed by biological activity due to low metabolic rates of sessile reef organisms during the winter, though water currents may sweep the reefs clean despite the lack of biological activity prior to the spring warm up and resumption of activity by the reef organisms. While some small amount of settlement is anticipated, a few inches, if the concrete structures sink into bottom substrate more than that, the reef structures could be pulled up and placed in a more stable area. This could even be achieved before the construction is complete as the construction time frame is a long enough period for any settlement to occur. Construction will be sequenced for the larger, heavier reef structures to be placed first and the lighter, smaller reef structures done last. This would allow for monitoring to be done after placement to address any settlement issues for the larger reef structures. The smaller reef structures are less likely to settle into the substrate as they are much lighter but lessons learned in the placement of the larger reefs structures would be utilized in the placement of the smaller variety.

Additionally, a local NGO, Lynnhaven River NOW has placed reef balls and other structures, including interlocking concrete "oyster castles" of the small variety that would be used in Lynnhaven Bay, in both nearshore and deeper water applications. The monitoring of these done by the NGO and the lessons learned they can provide would also serve to inform on what could be expected when placing the smaller reef structures and perhaps modify their placement area and design in order to achieve additional benefits, such as shoreline stabilization and increasing estuarine marsh acreage due to sediment accumulation and stabilization in the lee of the structures. Adaptive management measures will also be considered after major storm events, but only after ROV monitoring is done to assess the reefs and sufficient time passes to give the living organisms on the reefs to clean them off. Monitoring would be conducted after a storm event to determine if storm generated currents shifted or scowered underneath reef structures to cause shifting or settlement. Monitoring would generally be done in the latter part of the fiscal year but would be adjusted to react to a major storm event, which would typically be a hurricane. The results of the monitoring would determine the appropriate adaptive management measure as well as to inform if monitoring would be necessary after future storm events.

9.5.3.2 ***Reef Habitat Associated Costs*** **-** Hiring divers to clean off the reef structures would add approximately 2 percent to construction costs. Removing the reef structures from the sediment and possibly moving them to a more stable location would add approximately 10 percent to construction costs. Modifying the placement and/or designs of the reef structures as the project is phased in to take advantage of lessons learned from prior deployments should not add significantly to the construction costs of the project. $1,546,895 has been budgeted for adaptive management of reef habitat.

9.5.4 Submerged Aquatic Vegetation. SAV may require more extensive adaptive management than the other options of the selected plan. It is expected that once seeded, beds should persist and hopefully provide seed that will establish new beds in other locations in the river. Due to the technical challenges of SAV restoration, the project will be sequenced during implementation. Sequencing will occur so that several sites of one acre will be seeded at several of the locations recommended in the proposed plan. These sites will, at first, be mostly to entirely Ruppia, due to its greater tolerance for higher water temperature and general hardiness compared to Zostera. Variations in current energy will be one of the variables assessed, as SAV may perform better in areas with lower than average (for the Lynnhaven River) wave and current energy in the river, though the opposite may also be true. The objective of the sequencing is to assess the ability of SAV to survive and grow in the Lynnhaven without making the large commitment to seed wholesale the proposed project areas and make final adjustments to the large-scale seeding using the results of the initial acreages. These results in additional decision points in the SAV AM plan, compared to the fish reef AM plan. The basic SAV AM plan is explained graphically below:

Figure 30: ADAPTIVE MANAGEMENT PROCESS FOR SAV



The additional steps are due to many reasons, the first of which are the more variable track record of SAV restoration in Chesapeake Bay, SAV populations have been in general decline in the Bay, no large-scale attempt to restore it has been made in the Bay in some time. Additionally, prior attempts were using the older methods of transplantation of mature plants, not the modern methodology of direct seeding as proposed in the present study and focused almost exclusively on eelgrass, Zostera, not the hardier widgeongrass, Ruppia, that the present study recommends. The first decision point occurs after the initial acreages are seeded. If the SAV grows and survives, it is likely that the program will be expanded the following year. If not, results will be evaluated and a cause determined if possible. Additional sequenced plantings and research may be done to gather more data on local conditions, problems and opportunities for restoring SAV in the Lynnhaven River. For initial acreages, growth and survival of SAV is the objective. Initial sites may have predator exclusion (cow-nose ray) netting installed in order to prevent the rays, whose foraging habits can be disruptive to SAV, off the test plots. No specific density (shoots/m2) is required for the initial sites, though there are density objectives for the large-scale seeding as the density of SAV determines secondary production as well as the probability of long-term persistence.

Further sequencing and adjustments to seeding locations may be needed in the next phase, depending on what the cause was for the seeding failure. Reasons an initial seeding may not work as well as desired include, but are not limited to variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), excessive or insufficient water currents, or potentially a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. These can be fairly easy to determine and treat. Reasons a seeding may not work as well as desired include variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), or a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. Other reasons could be a local or regional decline in water quality, which would be more difficult to address.

Adaptive management measures would typically involve over-seeding beds to improve performance in the event that seeding does not take at desired densities in any selected area, abandoning a faltering site and moving a site or sites to regions of better current flow, anti-predator exclusion from the beds to discourage destructive foraging, better signage to discourage boat propeller damage or relocation of sites to areas of lower boat use. Passive actions are also possible, mainly waiting to see the results of a seeding and while gathering additional monitoring data to better influence decisions. The expected secondary production values for a fully successful SAV restoration attempt are displayed in the following table.

Table 22. SAV SECONDARY PRODUCTION OVER TIME

SAV Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	77.6
1	155.2
2	310.4
3	620.8
4	1008.8
5	1552.0

*year of initial seeding after first acres are completed with positive results

9.5.4.1 ***Submerged Aquatic Vegetation Adaptive Management*** **-** Seeding new areas that appear to be suitable but are not colonized by SAV could be implemented despite the success of the proposed beds in the selected plan. There may be subtleties in local hydrodynamics that prevent the propagules of successful beds from colonizing isolated regions of the river system, especially one as complex as the Lynnhaven.

Reasons a seeding may not work as well as desired are variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), or potentially a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. Summer heat waves can be challenging for SAV, especially Zostera. These can be fairly easy to determine and treat, except for weather-related impacts. Other reasons difficult to overcome via management decisions altering the construction plan could be a local or regional decline in water quality. In the cases involving physical damage to the beds, the cost to re-seed would approach 10% of the initial seeding costs to help low- shoot density SAV beds increase to the desired level faster, as the risk is that low density beds will continue to decline without intervention. Low density beds are those that have 10% or less of the area measured with SAV vegetation present. The Corps could also consider seeding in areas near established beds to encourage more rapid expansion. This option would cost less, up to approximately 5% of initial seeding costs. This measure would be employed if bed expansion does not occur, but the established bed persists at above low shoot density (if it does not, the entire bed will have additional SAV seeds applied within it).

Another measure could be to seed new areas that appear to be suitable but are not colonized by SAV despite the success of the proposed beds in the selected plan. There may be subtleties in local hydrodynamics that prevent propagules from successful beds from colonizing isolated regions of the river system, especially one as complex as the Lynnhaven. Monitoring results that assess current speeds within areas that develop SAV could be used to refine these choices. Such an option could cost 10% or more of the initial seeding costs, depending on the number of areas to be seeded. These sites will be identified post-initial construction, as these areas will not be apparent until SAV beds are established and expansion of the beds into new areas is documented. This will take at least 2 years after initial seeding to observe. Temperature data will be consulted, as the Lynnhaven River is near the edge of eelgrass' (Zostera marina) range and if the restored eelgrass dies back and the problem can be identified as temperature stress, the re-seeding may either only be with the more temperature tolerant widgeongrass (Ruppia maritima) or seed with more temperature tolerant eelgrass, if such can be found.

There is evidence that Zostera marina displays genetic differences regarding temperature tolerance (Ehlers et al 2008) but for local use no such strains have been identified at this time. Additional adaptive management actions could include signage requiring "no wake" zones over restored SAV beds, to reduce prop damage within the bed or possibly marking the SAV beds "off limits" to boat traffic, at least those located in shallow (< 3ft MLW) waters. This will be considered if prop damage to established SAV beds is observed. Such options would help existing, established beds maintain their integrity over time, as there is extensive boat traffic in the Lynnhaven. If the damage is due to cow-nose ray foraging, the only solutions are to protect the beds physically with nets or fencing, lower the numbers of rays (via a fishery, for example) attempt to restore SAV further upriver in lower salinity waters where cow-nose rays do not frequent (this option would likely preclude use of eelgrass and rely on widgeongrass only, as it is more tolerant of low salinity) and/or re-seed the beds.

If the SAV declines or fails to establish and the cause is determined to be poor water quality, the water quality monitoring data that is collected by the City of Virginia Beach will be reviewed for specific water quality issues. Eutrophication can occur in the event of a drought followed by above average rain events, and this can cause spikes in ChlA, DIN and DIP above levels tolerable by SAV. These levels should abate with time and the SAV, if still present, can recover. If not, and water quality improves it could be re-seeded. If the decline is caused by other events, such as a decrease in overall Bay water quality, seeding with eelgrass may not be implemented and only widgeongrass, the more environmentally tolerant species, may be used until water quality improves sufficiently to warrant eelgrass establishment. If enough SAV can be established, these parameters are less likely to be exceeded as SAV itself utilizes the same nutrients that can cause phytoplankton blooms due to eutrophication.

In any area that is difficult to access by boat or if currents are strong or irregular, buoy deployed seeding would be utilized. This technique helps insure that the seeds, when dispersed, stay in an area around the buoy by releasing them slowly over time. This process lets the dispersal take place across a variety of conditions and would mitigate the risk of losing broadcast seeds due to storm events or currents shortly after the seeds were cast to the water (Pickerell, et al. 2006).

Decision points are after every year's monitoring. If results are at least 50% of expected secondary production values, the project will likely require no AM action other than continuing to monitor the site(s) to see how they progress. If the original effort to establish SAV is not successful, the project area will be reseeded unless it is determined that there is an underlying cause that cannot be addressed, such as unfavorable current velocity that could not be altered by reef placement, in which case a particular site(s) may be abandoned. Re-seeding should also take place if the SAV beds are only scarcely vegetated (density ≤ 10%), as additional seeding will help low-density SAV beds increase to the desired level faster and reduce the risk that the low density beds will continue to decline without intervention.

If secondary production values are not meeting at least 50% of the objective, a decision point is reached. If this failure is due to disruption of the SAV by weather events, unless total loss occurs the likely decision will be to wait to see if enough seed and underground rhizomes remain to recover the bed, as SAV is resilient in the face of this type of event and can often recover, once established, on its own due to available seed and rhizomes, which often remain buried in the sediments while above ground biomass is swept away by the storm event. If the failure is determined to be from a water quality cause, such as a heat wave, waiting is the likely recommendation unless total loss of both above and below sediment SAV has occurred, in which case re-seeding is recommended. If the cause is physical damage (boat props and/or cow-nose rays) measures can be taken to discourage this, including signage and physical barriers.

9.5.4.2 ***Submerged Aquatic Vegetation Associated Costs*** **-** The cost to re-seed would approach 10 percent of the initial seeding costs, while seeding in areas near the established beds would cost less, up to approximately 5 percent of initial seeding costs. Seeding new areas, outside of the project site, could cost up to 10 percent of the initial seeding costs, depending on the number of areas to be seeded. "No wake" signage would have minimal associated costs, perhaps 1-2 percent of initial seeding costs. $42,676 is the estimated cost of adaptive management for SAV.

9.5.5 Bay Scallop Restoration. Scallop restoration will only be attempted if core bed acreage (the minimum SAV option as described in the attached report) is at least present, as scallops are highly (though not exclusively) dependent on SAV as shelter for their juvenile stage. Scallop restoration will only proceed if several beds of SAV can be restored and show persistence by surviving for several years. The scallop is a short-lived mollusk and in the Lynnhaven will essentially function as an annual crop, though some can survive for two years. Once established, and assuming the SAV persists, the scallops should persist along with the SAV. However, scallops are vulnerable to predation and possibly environmental disruptions, such as major storm events. The restoration efforts will, similar to SAV, begin with smaller introductions and increase from there.

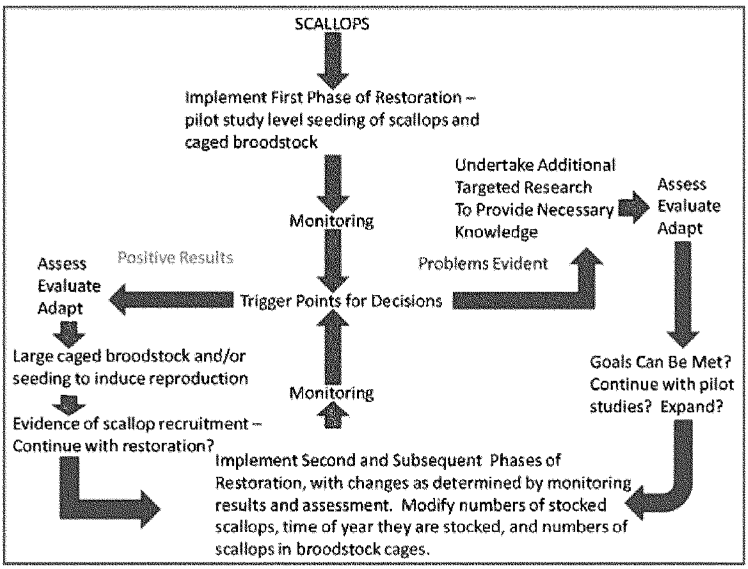
The objectives of the initial sequencing is to determine if scallops reproduce in the Lynnhaven as well as gather data on the most efficient means to restore a breeding population. It is expected that these efforts will be less and shorter in duration than those for SAV, as the Corps has already funded a large-scale study on scallops in the Lynnhaven River (Hernandez-Cordero et al. 2012). The results of this study indicated scallops can survive and grow in the Lynnhaven River on a variety of habitats, including oyster reefs, SAV, and macro-algae. The sequencing will focus on how best to implement wide-scale restoration, as there are a number of techniques available, including keeping spawning adults in cages so they spawn at high efficiency, release of juveniles and/or adults into SAV beds, to potentially releases late-stage larvae into SAV beds. It is expected that a combination of efforts, likely focusing on caged adults with some stocking of juveniles, is the likely restoration regime but the sequencing will assist in fully developing this plan. Expected productivity for scallops is described in the following table:

Table 23. SCALLOP SECONDARY PRODUCTION OVER TIME

Scallop Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	11.5
1	22.9
2	45.8
3	91.6
4	148.9
5	229

9.5.5.1 ***Bay Scallop Adaptive Management*** **-** Scallop restoration will only be attempted if core bed acreage (the minimum SAV option) is at least present, as scallops are highly (though not exclusively) dependent on SAV as shelter for their juvenile stage. Scallop restoration will only proceed if several beds of SAV can be restored and commence *at least* 1 year after successful SAV bed establishment. Once established, and assuming the SAV persists, the scallops should persist along with the SAV. They will also colonize other habitat, such as macroalgal beds (Gracilaria sp.), and oyster reefs in significant numbers. However, scallops are vulnerable to predation, and possibly environmental disruptions such as major storm events. The basic scallop AM decision tree is as follows:

Figure 31. ADAPTIVE MANAGEMENT PROCESS FOR SCALLOPS



There are several adaptive management measures that could be considered in scallop management, as follows. As with prior portions of the plan, the objective is to reach at least 50% of the secondary production goal. For scallops, evidence of successful reproduction is also a requirement and the establishment of a self-sustaining population is a primary objective, along with the secondary production goal.

In order to reduce risk from predation, the corps could consider fencing off limited areas (perhaps 10X10 square meter plots) within SAV beds determined to be the main areas supplying scallop recruits to other areas. The predator that can cause the most extensive damage to a scallop population, the cow-nose ray, would be kept out by such a measure. The Corps could then preferentially stock within these predator exclusion areas, in order to better insure initial survival. The Corps could also stock at very high densities within these fenced areas, in order to improve reproduction of the scallops to enhance recruitment. This is a relatively inexpensive measure, and would be up to 5% of the initial seeding costs. This predator exclusion could also be done if re-seeding is required, and done more extensively. In this event, up to 10% of initial costs would be necessary; to cover the addition of hatchery produced juvenile scallops within the fenced-off areas.

Other adaptive management actions could include collecting juvenile scallops on volunteer or contractor deployed spat bags placed under docks or within or near existing SAV beds and then stocking these juveniles more heavily within established SAV beds to increase the population density of the scallops in order to improve both the environmental benefits they provide as well as their reproductive efficiency. Due to the extensive environmental group membership in the local area, it is likely that such spat collecting done by volunteers could be quite extensive and contractor deployed spat collectors used less extensively as a result. Costs for spat collecting would likely be relatively small, perhaps up to 5% of initial seeding costs. This measure will likely be considered if recruitment does not seem sufficient or if the need to collect additional data on recruitment is needed beyond the scope of the proposed monitoring plan.

A further adaptive management measure would be to deploy scallops in cages at very high densities to maximize reproduction and subsequent recruitment. This will be considered both in the initial stocking as well as if recruitment does not appear to be adequate to establish a self-sustaining population and additionally seeding proves necessary. Such techniques are showing success on the lower Eastern Shore of Virginia in re-establishing scallops in restored SAV beds there.

Predator control via commercial fishing of the rays could also be considered, and is currently under discussion by the state fishery management agency (Virginia Marine Resources Commission (VMRC)). This is due to the noted increase in cow-nose rays in recent years, which also cause extensive mortality to clam beds and commercial oyster lease holds. Predator control would consist primarily of developing a commercial fishery for cow-nose rays, which, while not a USACE action, the USACE will provide input to VMRC.

After each year's monitoring, the scallop population will be assessed. Three basic questions will trigger decision points, and these are: Is there evidence of successful reproduction? Are numbers of adults increasing? Are secondary production goals being met? Failure to meet any of these three will trigger the AM plan.

In the event of unsuccessful reproduction, unless a weather event, such as a hurricane, can be identified as the cause, the likely cause is too few spawning adults. In either event, the appropriate response is to augment the spawning population the following year in order to avoid a population crash. This can be done using any of several techniques described above, particularly stocking of juveniles and/or adults directly into the SAV beds or placement of spawning adults in cages near SAV beds which will release larvae into them.

If the population of adults appears to be reproducing, but decreasing in numbers, this may trigger an AM response. SAV beds should first be assessed for their fitness, as decreasing shoot density exposes the scallops to increased rates of predation. Evidence of cow-nose ray feeding within SAV beds should also be assessed. Cow-nose rays disrupt the bottom when they feed, creating a hole approximately 1foot in diameter and 6" deep. Large numbers of these holes in SAV beds would identify the ray as the primary culprit in decreasing numbers of adult scallops despite successful reproduction. Anti-predator exclusion netting is the cheapest measure to discourage the rays, though if a fishery for them could be developed, this would also ease their predation pressure on the scallops as well as other benthic life in the Chesapeake Bay though this action is outside the AM plan. Other causes could be inadequate recruitment. This could be caused by poor water quality during the larval phase, particularly large inputs of freshwater which reduce larval survival and growth, as well as flush them out of the river into the Bay. The appropriate AM response in this case will be to augment the spawning stock by means already described.

Failure to meet secondary production goals will also trigger the AM plan. If the scallops appear to be reproducing and adults are surviving in adequate numbers to produce a self-sustaining population (or one that seems to be increasing) no action should be taken and a “wait and see” approach is recommended. Scallops may develop a stable population at a lower than expected level in the SAV beds, considering that they can survive on other substrate that is present in large amounts (macroalgal beds, oyster reefs) in the Lynnhaven River. These scallops on alternative substrates could provide significant secondary production such that goals are actually exceeded, though not exclusively via the scallops in the SAV beds habitat. Routine monitoring of the oyster reefs built under the 704(b) program would provide some data on scallops utilizing this habitat type. Additionally, this goal may need to be reassessed if this situation occurs, as the primary objective is to establish a self-sustaining population of scallops. The secondary production numbers were developed using more southern populations of scallops, and the numbers for Lynnhaven River’s distinct scallop sub-population may be somewhat different.

9.5.5.2 ***Bay Scallop Associated Costs*** - Fencing off areas within SAV beds is a relatively inexpensive measure, and would be up to 5 percent of the initial seeding costs. If predator exclusion is done in conjunction with SAV re-seeding, then the associated costs would be as high as 10 percent of initial costs to cover the addition of hatchery produced juvenile scallops within the fenced-off areas, while the costs associated with spat collection would likely be relatively small. Adaptive management of bay scallops is estimated at $66,555.

9.5.6 Wetland Restoration and Diversification. The monitoring and adaptive management (AM) plans for the two different wetland treatments will vary slightly due to the overall project objectives.

9.5.6.1 ***Wetland Restoration and Diversification Adaptive Management*** **-** Using the data collected through the monitoring program, USACE staff will be responsible for determining if AM is required at the wetland sites. The USACE will also select the AM measures, though other experts maybe consulted. Contractors with the appropriate background and expertise may be hired to implement the AM efforts; however the USACE will oversee the completion of adaptive management activities. AM measures are primarily herbicide application and replanting of native vegetation. Species of native vegetation may be altered, pending monitoring results, as different species than those initially selected may survive better considering the hydrology of the sites several years post-grading as well as the need to compete with other plants, including nearby Phragmites. Depending on the site, the replanting may vary the species in order to improve subsequent survival, as initial choices may not have been ideal, based on how the site performs over time.

A number of different strategies have been used to manage Phragmites. These include burning, mowing, manual removal of plant material and the application of herbicides. Since Phragmites management has been a recurring problem along the Eastern sea board for many years, other management plans have included common elements. So although any of previously listed actions will be available for AM of the wetland sites, it is highly probable that certain actions will be part of the plan. These actions, the application of herbicides, replanting native salt marsh vegetation, or repairing marsh features (pools, stream, or islands), are discussed in further detail in this report. However, this does not preclude the use of any effective strategy that will allow the project to fulfill the environmental objectives.

Restoration Sites If P. australis is found within the restoration site, herbicide, approved for aquatic use, will be applied to the invasive species. The method of application (whether ground or aerial) will be determined by the location and density of invasive plants. The application of herbicide will occur when P. australis is still active, but when the native marsh plants have gone dormant, in order to reduce unintentional damage to the plantings and native plants. This period typically occurs during the last two weeks in September; however, this timing may be altered during drier years. The timing of herbicide application will be altered if annual precipitation levels are below normal levels.

If more than 15 percent of native plantings have failed, the dead vegetation will be replaced with plants for the same species. If it is concluded that replacing the original planting will ultimately be unsuccessful, then another solution (e.g. planting another species) may be implemented.

The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water moves freely through the channel. If the stream is occluded, the feature will be repaired to allow flow.

The shallow pools should remain open and free from vegetation. If the areas are beginning to be colonized by P. australis, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be checked for the success of native shrub plantings and re-colonization by P. australis. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings would be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands. If P. australis has re-colonized the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the plant from the habitat features.

Diversification Sites The habitat features created at the GNS and MDC sites will be observed for colonization of P. australis. If P. australis is found on the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the common reed from the habitat features. The shallow pools and tidal creeks should remain open and free from vegetation. If the areas are recolonized by P. australis, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be monitored for the success of native shrub plantings. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings will be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands.

The integrity of the habitat features will also be evaluated. The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water flow moves freely through the channel. If streams are blocked, the feature will be repaired to allow flow. The integrity of the open pools and islands will also be observed to ensure that they are fulfilling their original purpose (i.e. increase habitat diversity at the site). If it is determined that the features are not improving the function of the site, they will be modified in order to meet project goals. Secondary production will also be assessed.

These values are closely tied to the success of the plantings, and as wetlands restoration methods are much more well-established than other portions of the plan, it is expected that if the plantings survive, these values will be achieved. The AM plan is triggered in the event of excessive casualties of the plantings, which directly relate to the values provided in Table 24.

Table 24. WETLANDS SECONDARY PRODUCTION OVER TIME

Wetland Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	12.1
1	24.2
2	48.4
3	96.8
4	157.3
5	242

9.5.6.2 ***Wetland Restoration and Diversification Associated Costs*** **-** It is foreseen the certain adaptive management actions, such as the application of herbicide and the replacement of native plantings, will occur annually. Larger actions, such as the restoration the integrity of habitat features, requiring the physical alteration of the site will be planned every 5 years. The monitoring and adaptive management program will take place over a 10-year period.

The adaptive management costs associated with the wetland sites is $93,755.

9.5.7 Adaptive Management Determination and Closeout. The monitoring program and pre and post construction surveys would be utilized to determine if any adaptive management is needed and what kind to proceed with. This determination would be made by the project delivery team made up of personnel from the Corps of Engineers and the City of Virginia Beach. Costs for the AM decision process have been included in monitoring cost estimates. AM measures will be implemented at any time over the first 10 years post construction by the USACE. After that, if AM is required, it will be the responsibility of the local sponsor, the city of Virginia Beach.

9.6 Additional Ecological Improvements Resulting from the Recommended Plan

The recommended plan will provide many other environmental improvements to the Lynnhaven River System in addition to secondary production and diversity, the two environmental benefit parameters used to quantitatively justify the project.

9.6.1 Alteration of Stable State. In ecology, alternative stable state theory asserts that changes in ecosystem conditions can result in an abrupt shift to the state of the ecosystem, creating a new state that can be stable and persistent (Scheffer et al., 2001; Lewontin, 1969). Such ecologically stable states are also resilient. Ecosystem resilience is the capacity of an ecosystem to tolerate environmental disturbance without collapsing into a qualitatively different state (positive or negative) that is controlled by a different set of processes. Thus, stable states can tolerate additional impacts and can be difficult to alter by restoration attempts (Suding et al, 2004). The likelihood of significantly altering the stable state of the system is greater with a large scale and diversified project, such as the one recommended in this report.

Environmental conditions in the Lynnhaven River started to become impaired around the turn of the 20th century. During the 1970's, river conditions seemed to stabilize in an alternative stable state, one degraded from the original condition but persistent and difficult to change (Beisner et al., 2003). This degraded condition has been a fairly stable ecological state that has persisted for years. That condition was due to the reduction in the population density of primary filter feeders, in this case oysters, as well as negative shifts in underlying environmental drivers such as increases in TSS, nitrogen, and phosphorus related to accelerated human habitation and development of the Lynnhaven River Basin. Increases in nitrogen and phosphorus drove primary productivity up, in this case phytoplankton, thus increasing chlorophyll *a* levels throughout the river (as well as Chesapeake Bay in general).

The current Lynnhaven River condition represents a complex situation with both biotic (living) and abiotic (non-living) factors are influencing the system together. For the Lynnhaven River, this has resulted in extensive loss of natural biota, including near total losses of oyster reef habitat, structure dependent fish, SAV, and benthic diatoms as well as the extirpation of Bay Scallops (which likely happened in the 1930's if not earlier), with little likelihood for natural recovery. Species diversity has been negatively compromised and remains so with little hope for improvement without significant increases in diversity habitat. Abiotically, high levels of TSS and nitrogen compounds have become the normal state for water throughout the river. The ecological feedback resulting from altered abiotic factors and loss of reef and SAV habitat will continue to inhibit the recovery to a healthier, ecologically stable state unless large scale environmental manipulation is successful. Such manipulations can be human or environmentally induced.

The Lynnhaven Ecosystem Restoration Study assessed a wide variety of options and a Recommended Plan was identified. This large-scale manipulation of the river system involves restoration of degraded wetlands and manipulation of wetlands to increase vegetative and concomitant animal species diversity in the near shore environment. Aquatic restoration efforts include restoration of SAV beds, a re-introduction of Bay Scallops within the SAV beds, and replacement of lost 3-D subtidal oyster reefs with high-relief fish reefs which will function as both oyster reefs and fish reefs once they are colonized by oysters and their related epifauna. All of the proposed restoration activities will be done at scales large enough to potentially influence conditions in the Lynnhaven River Basin, which is needed in order to achieve a return to an alternative stable state more representative of an earlier, more pristine ecology. The Recommended Plan will attempt to restore the river to a state dominated by reef-building filter feeding bivalves, SAV beds, scallops, native wetlands, and benthic diatoms in contrast to one currently characterized by waters with high levels of TSS and eutrophic conditions with high levels of phytoplankton and low levels of secondary production.

9.6.2 Total Suspended Solids. Another environmental parameter that will be improved by implementation of the Lynnhaven restoration project is the reduction of TSS levels in river. TSS is a common measure used to estimate negative human-induced impacts to aquatic ecosystems. Quantities of TSS higher than pre-development levels produce a number of negative environmental impacts. TSS reduces gas exchange, increasing the chances for anoxia in tidal estuaries (Abril et al., 2009). TSS reduces water clarity and its increase from human impacts, primarily resulting from agriculture and urban development in the Chesapeake Bay watershed, has greatly reduced the available habitat for SAV (Tomasko et al., 2005). SAV stabilizes bottom sediments and its loss creates a negative feedback loop where TSS tends to increase further, making it increasingly difficult for light-dependent marine life to persist, especially rooted aquatic vegetation. Additionally, TSS reduces the available habitat for other photosynthetic life such as benthic diatoms (Ulanowicz, 1992), altering the species composition along with the associated local estuarine ecosystem and food webs.

TSS also stresses filter feeding organisms, such as oysters, making them more susceptible to disease (Colosimo, 2007). This has been a major cause in their population collapse in recent decades. Additionally, when TSS is high, oyster reefs can become covered with a fine layer of silt that quickly renders the reef substrate unsuitable for oyster larval attachment. However, functional oyster reefs or other hard substrate colonized by oysters and other filter feeders can substantially reduce TSS as they filter feed. TSS typically becomes incorporated into their waste and often ends up deposited on the bottom out of the water column.

Fish species that require hard substrate for benthic egg laying cannot use silt covered habitat for reproduction. Other reef dependent species, such as naked gobies, tautog, and other finfish, suffer from this loss of habitat. Other filter feeders, such as clams and menhaden fish, are also negatively affected by high TSS levels because they must process and eliminate the excess TSS during their filter feeding (Soniat et al., 1998), which uses energy that could otherwise be used for somatic growth or reproduction.

Another negative impact associated with high levels of TSS is increased levels of *E. coli* and other pathogenic bacteria. Such organisms are not commonly found freely living in the water column, because they usually attach to small particles of suspended sediment instead (Schillinger et al., 1985). Thus, lowering TSS levels may have some beneficial effects on pathogenic bacteria levels by lowering them and thereby improving water quality.

There are numerous input factors that influence the TSS levels measured during routine monitoring in the River. However, it is estimated that the Recommended Plan will result in an average annual reduction of 928,000 kg TSS. Table 25 provides an estimate of the amount of TSS that would be removed from the Lynnhaven River Basin annually as calculated by the VIMS Hydrodynamic model.

Table 25. RESULTS OF VIMS HYDRODYNAMIC MODEL RUN WITH RECOMMENDED PLAN

	Chlorophyll A Reduction, Average Annual %	TSS Reduction, Average Annual %
Lynnhaven Bay	13%	17%
Eastern Branch	12%	38%
Western Branch	14%	36%
Broad Bay	16%	74%
Linkhorn Bay	17%	61%

9.6.3 Restoration of Lost Habitat Types. The Recommended Plan focuses on restoration of two valuable habitats, fish reefs and SAV, that once had a dominant presence in the Lynnhaven River System. Both were completely removed from the Lynnhaven River and more recently have played a very minor role ecologically. As described earlier in the report, reef habitat was lost due to the elimination of the oyster population resulting from overharvesting and disease. SAV beds were lost from the system as a result of poor water quality. Recovery of both SAV and oysters is an effective strategy to initiate significant and positive ecological change. The projected outcome is a shift to a more positive, stable ecological state stable enough to promote additional natural recovery over time.

The both habitat types function as ecosystem engineers. Ecosystem engineers are organisms that either create or significantly modify habitat (Jones et al., 1994). The fish reefs will function as hard reef habitat and will be heavily colonized by filter feeders. The most prominent of which, the eastern oyster, creates additional reef habitat as clusters of oyster break off, settle on the bottom, and continue to grow. The concrete structures and the colonizing oysters also provide structure for other marine life. SAV modifies habitat by stabilizing bottom conditions, baffling wave energy, and providing shelter to a wide variety of marine organisms. Development of this habitat, in turn, is expected to increase and improve the diversity and abundance of marine life in the Lynnhaven River system.

As stated earlier, alternative stable states are difficult to alter and are one explanation of why degraded ecosystems are often difficult to restore. Ecosystems that are the most difficult to restoration are those that are heavily controlled by abiotic factors (Didham et al., 2005). The Lynnhaven River is such an ecosystem, one where heavy human development in the Basin has increased TSS and created eutrophic conditions. The abiotic environment, which includes such things as basic water quality parameters like total nitrogen and phosphorus, can be greatly modified by biological ecosystem engineers. These organisms are often the agents of change between alternative stable states (Rietkerk et al., 2004). A large scale restoration using available ecosystem engineers, therefore, is likely the best means to effect change on a watershed scale.

If the restoration and modeled benefits are achieved, there should be significant water quality improvements related to habitat in the Lynnhaven River. Such improvements could allow the restored SAV beds to expand to additional suitable shallow water habitat as both water quality and water clarity improve. Similarly, oysters and their associated epifauna will expand their range as existing marginal bottom habitat becomes more suitable. Scallop populations will establish themselves in any new SAV bed in the high-salinity regions of the Lynnhaven River and though some expansion is possible, it will be more limited due to the scallop's narrower salinity tolerances compared to oysters and SAV. Coupled with the City of Virginia Beach's efforts to control storm water runoff and reduce anthropogenic nutrient inputs to the river, additional ecological benefits could also be realized. Additional benefits are related to positive feedback loops created by the improvements in biotic factors (e.g. SAV and oyster restoration) and improvement in the abiotic factors (e.g. water quality) via continued improvement efforts (Suding et al., 2004) by the City of Virginia Beach. Overall, the selected plan's benefits are forecasted to be significant and are expected to make a visible contribution to the ecological health of the entire Lynnhaven River system.

9.6.4 Dissolved Oxygen. The selected alternative is also predicted to have a positive impact on the DO levels in the Basin. SAV will directly add oxygen to the water column through the process of photosynthesis. The installation of reef habitat is also predicted to have an even larger impact on DO levels than the restoration of SAV beds. It is expected that significant numbers of oysters will colonize the concrete reef structures. This mollusk species is a filter feeder and will remove large quantities of TSS from the water column, which will impact DO levels. Large concentrations of TSS can reduce the amount of oxygen in the water column through a number of mechanisms. TSS absorbs the heat from sunlight, which results in increased water temperatures and decreased DO levels because warmer water holds less oxygen than cooler water. TSS in the water column also will reduce water clarity and inhibit photosynthesis when less light penetrates the water. As a result, less oxygen is produced by plants and algae and there is a further drop in dissolved oxygen levels. Then as the biologic component of TSS falls out of the water column and decomposes, DO is removed from the water column.

9.6.5 Executive Order 13508 on Chesapeake Bay Protection and Restoration. The primary goal of the proposed project is to improve the local ecosystem, which is a tributary of the Chesapeake Bay. The Chesapeake Bay has national significance and was recently the subject of an EO. This Order, 13508, is entitled "Chesapeake Bay Protection and Restoration" contains specific goals for restoration the Chesapeake Bay. One of the main features of the goals is its tributary by tributary strategy and advancing the Lynnhaven Feasibility Study is identified as an action for FY 2011. The proposed project, along with prior oyster shell reef restoration efforts by USACE in 2007 and 2008, will likely enable the listing of the Lynnhaven River as one of the first successfully restored tributaries.

10.0 PLAN IMPLEMENTATION

10.1 Project Schedule

Table 26 shows the schedule through initial construction for the Recommended Plan. This schedule assumes expeditious review and approval of the project through all steps, including authorization and funding. Actual project implementation could take longer. This schedule is subject to availability of funds. The final feasibility report and signed Chief's report must be submitted to Congress, having received Executive Branch approval, by August 31 two years prior to the fiscal year in which construction would start.

10.2 Division of Plan Responsibilities

10.2.1 General. The costs of USACE water resource studies and projects are shared between the Federal government and the non-Federal interest (sponsor), in accordance with the cost sharing requirements outlined in Federal law that are usually stated as percentages for the shares. These costs are then apportioned between the Federal government and the non-Federal sponsor. For projects that provide ecosystem restoration, the purposes are usually (1) ecosystem restoration and (2) separable recreation. For the Lynnhaven River Basin project there is no separable recreation component.

TABLE 26. PROJECT SCHEDULE

Item	Date
Alternatives Formulation Briefing Conducted	25 April 12
Draft Feasibility and Integrated EA Submitted for Concurrent Review to Higher HQ and Agencies and Public Review	26 April 13
Final Feasibility and Integrated EA Submitted	12 July 13
Civil Works Review Board Conducted	24 September 13
Final Feasibility and Integrated EA Distributed for State and Agency Review	05 October 13
FFR and Signed Chief's Report Submitted to ASA	February 14
FFR, Signed Chief's Report, and Signed FONSI Submitted to OMB	April 14
FFR, Signed Chief's Report, and Signed FONSI Submitted to Congress	June 14
Design	July 14
Water Resources Development Act Passed Giving Construction Authorization	*FY16
Project Partnership Agreement for Construction	February 16
NTP with real property acquisition	March 16
Real Estate Acquisition Complete	March 18
Certification of Chief of Real Estate	**February 17
Construction	February 17

*The date of the WRDA passing is an estimate; therefore all dates after the passage of the WRDA are also estimates and are not guaranteed.
**The project will be constructed in phases. It is estimated that the real estate for the first phase of the project will be completed within a year of the PPA being signed; which will allow certification from the Chief of Real Estate by Feb 2017. Certification from the Chief of Real Estate will be obtained for the other phases of construction as realestate is acquired.

10.2.2 Cost Sharing. The study costs are shared (50 percent Federal, 50 percent non-Federal) in accordance with the Feasibility Cost Share Agreement which was executed on September 22, 2004 between the Department of the Army and the City of Virginia Beach, Virginia. For specifically authorized ecosystem restoration projects the costs of construction shall be shared with the non-Federal sponsor, the City of Virginia

Beach. The Federal share will be 65 percent and the non-Federal share will be 35 percent of total project costs, including all applicable costs related to preconstruction, engineering and design, and construction of the project. The non-Federal sponsor shall provide all lands, easements, rights of way, relocations and dredge material disposal areas (LERRD's) determined by the Government to be necessary for the project, and be responsible for performine all required project operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). The costs of LERRD's are included in the total project costs and effectively cost shared through the crediting of their value toward the sponsor's share. The value of LERRD shall be included in the non-Federal 35 percent share. The value of LERRD's is estimated at $725,000. The cost sharing for the project is shown in Table 27.

TABLE 27. PROJECT COST SHARING

Item	Total Costs
Construction	27,148,000
Adaptive Management	1,750,000
Lands, Easements, and Rights of Way	725,000
Construction Management	2,127,000
Preconstruction, Engineering, and Design	2,663,000
Total First Costs	34,413,000
Federal Share (65%)	$ 22,368,000
Non-Federal Share (35%)	$ 12,045,000

10.3 Views of the Non-Federal Sponsor

The Recommended Plan has been developed by a Steering Committee comprised of the non-Federal cost sharing sponsor, USACE, Lynnhaven River NOW, and other local and governmental representatives. The monthly meetings of this committee have provided many opportunities for input, discussion, and endorsement as the plans have evolved through the reconnaissance and feasibility study processes. The Recommended Plan, which has developed over this time, is acceptable to and enthusiastically supported by the City of Virginia Beach and Lynnhaven River NOW. There are restoration activities located throughout the Basin, lending local political and community acceptance to the plan. Because the Lynnhaven River Basin is a spawning and nursery habitat for many aquatic species, the NER plan will have far reaching effects throughout the river system, the Chesapeake Bay, and beyond.

10.4 Views of the U.S. Fish & Wildlife Service

The Norfolk District coordinated with USFWS throughout the entire planning process. Views of the USFWS were provided in a draft Fish and Wildlife Coordination Act Report, which can be found in the Environmental Appendix. The USFWS supports the Lynnhaven ecosystem restoration project and believes that the project will increase productivity of the Lynnhaven Bay system. The major recommendations from the report are:

- Monitoring should occur frequently shortly after planting to determine if animal disturbances such as grazing will be a problem. If the site is being disturbed at such a level that will be detrimental to its success, then additional protective measures should be considered. In addition, many contractors will provide a one year guarantee that all plant material is healthy but it is not specified who is responsible for monitoring for survival or if monitoring will be assessed following a specific protocol. If it is determined that replanting is needed, the contract should guarantee the replanted material for a year from when they are planted. The Service is also concerned about the potential for erosion and colonization by invasive species until the vegetation is established. A comprehensive monitoring program is needed to ensure the success of this restoration project.

- Because the success of the bay scallop restoration is contingent on successful SAV restoration, we recommend monitoring SAV health for a minimum of two years after restoration activities. Reseed the SAV restoration sites that do not meet the preestablished success criteria.

- Aerial herbicide spraying should only be conducted if wind speeds are less than five miles per hour (mph). Wind direction is a lesser consideration because spraying will only occur at wind speeds of less than five mph. The likelihood of precipitation should be considered when making the decision to spray. Weather forecasts and onsite conditions should be monitored before, during, and after spray operations. A chance of precipitation less than 30 percent within four hours prior to the start of spraying will result in a decision not to spray for that day. During herbicide treatment, the wind speed and direction, aircraft speed, spray altitude, and spray mist/droplet size should be monitored continuously.

SAV restoration efforts could be hampered or negated by mute swans. Legislation HR 4114 that proposes to remove protection of exotic species from the Migratory Bird Treaty Act is before Congress. The USFWS recommends that the mute swan population be monitored and that USACE work with the USFWS and the VDGIF to develop a response plan in case mute swans begin to negativity impact the restoration sites.

11.0 ENVIRONMENTAL IMPACT EVALUATION

11.1 Aquatic Resources

11.1.1 Wetlands. EO11990, "Protection of Wetlands," was enacted to avoid the further destruction or modification of wetlands. The EO directs Federal agencies to "minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands." The Lynnhaven Restoration Project fulfills the mandate of this EO.

Three elements of the Recommended Plan, SAV planting, reef habitat installation, and Bay Scallops, will have no impact on wetlands. These components occur in subtidal areas of the Lynnhaven River. Therefore, no jurisdictional, vegetated wetlands exist within the footprints of these restoration elements.

The fourth major part of the Lynnhaven Project involves the restoration of four wetlands. All the restoration areas are included in the Fish and Wildlife Service's National Wetlands Inventory. Three of the four sites (GNN, GNP, and PA) are identified with the code E2EM1P. The description code identifies the areas as:

E System ESTUARINE: The Estuarine System describes deepwater tidal habitats and adjacent tidal wetlands that are influenced by water runoff from and often semi-enclosed by land. They are located along low-energy coastlines and they have variable salinity.

2 Subsystem INTERTIDAL: This is defined as the area from extreme low water to extreme high water and associated splash zone.

EM Class EMERGENT: Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.

1 Subclass Persistent: Dominated by species that normally remain standing at least until the beginning of the next growing season. This subclass is found only in the Estuarine and Palustrine systems.

P WATER REGIME Irregularly Flooded: Tidal water floods the land surface less often than daily.

The MDC site is described with the code PFO1R, which identifies the site as:

P System PALUSTRINE: The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, emergents, mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5 ppt. Wetlands lacking such vegetation are also included if they exhibit all of the following characteristics: 1. are less than eight hectares (20 acres); 2. do not have an active wave-formed or bedrock shoreline feature; 3. have at low water a depth less than two meters (6.6 feet) in the deepest part of the Basin; 4. have a salinity due to ocean-derived salts of less than 0.5 ppt

FO Class FORESTED: Characterized by woody vegetation that is six meters tall or taller.

1 Subclass Broad-Leaved Deciduous: Woody angiosperms (trees or shrubs) with relatively wide, flat leaves that are shed during the cold or dry season; e.g., black ash (*Fraxinus nigra*).

R WATER REGIME Seasonal-Tidal: Palustrine, Riverine, and Lacustrine wetlands that are flooded by fresh water tides for extended periods especially early in the growing season, but is absent by the end of the growing season in most years are seasonally flooded-tidal. The water table after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface.

At two of these sites, an invasive wetland plant species will be removed and the native tidal salt marsh community will be restored. At the remaining two sites, a native plant community cannot be restored as described in previous sections of the report. Instead, habitat features will be constructed in order to improve the function of the existing marsh. The modifications to the wetland sites will be completed through physical alteration of the existing topography and application of herbicides. These actions may result in short term impacts such as exposure of marsh sediment, damage to native wetland plants currently at the site, and mortality of sessile or slow moving organisms that inhabit the project area. Quick moving creatures may be frightened away from the area resulting in the disruption of their behaviors.

Regrading or removing of material from the marsh surface will result in exposed sediment that could enter the waterway and increase the turbidity of adjacent tidal streams. Materials generated from sediment excavation activities at the wetland restoration sites and disposed of at landfill facilities will be evaluated as a solid waste in accordance with HTRW guidance as appropriate. Best management practices will be used to control runoff and sedimentation until the plantings become established. Overspray of the herbicide may damage native marsh plants. Unintentional damage will be minimized by timing the spraying to correspond with the period in the fall when native vegetation has gone dormant but the *Phragmites* is still active. The motile wetland species are expected to return to the sites once construction has been completed. In areas that have been physically altered and replanted, the marsh community will return. However, the reestablishment of normal levels of biodiversity and biomass will be gradual.

The long term impacts of wetland restoration will be positive in nature. Fish and wildlife usage and habitat diversity would be enhanced with the restoration of wetlands at these sites. The indigenous salt marsh community will be reestablished at two sites. The possible short term impacts related to the Recommended Plan would be outweighed by the benefits which restored wetlands would provide.

The current design of the Recommended Plan complies with the criteria of Nationwide Permit (NWP) #27 "Aquatic Habitat Restoration, Establishment, and Enhancement Activities." All the alterations that will occur at the wetlands sites are allowed by this NWP, including the removal "of non-native invasive, exotic, or nuisance vegetation," "activities needed to reestablish vegetation," "planting of appropriate wetland species," "removal of accumulated sediments," "construction of small nesting islands," and "construction of open water areas." Even though this work complies with the criteria of a NWP, USACE will acquire permits from VMRC and the Virginia Beach Wetlands Board via Virginia's joint permit application (JPA) process. A 401 Water Quality Certification will be obtained from the Division of Water prior to construction. The Section 404(b)(1) Evaluation and Compliance Review has been incorporated into this report.

The NAA (No Action Alternative) would result in no impacts at three of the four wetlands sites (PA, GNS, and MDC). These sites are completely dominated by *Phragmites australis*. If no action is taken, it is unforeseeable that this condition would be altered. If no action is taken at the GNN site, conditions may degrade as the *Spartina* community is replaced by the invasive *P. australis*. Areas adjacent to a supply of *Phragmites* seeds and rhizomes or in areas that are not flooded by tidal water at regular intervals will be especially susceptible to *P. australis* colonization.

11.1.2 <u>Submerged Aquatic Vegetation</u>. Very small SAV beds currently exist in the Lynnhaven Basin. Although populations have existed in the past, these beds have disappeared almost entirely over time due to poor water quality and increased sedimentation. The existing SAV beds will benefit both directly and indirectly from the implementation of the Lynnhaven Restoration Project. Direct benefits to SAV habitat will be gained through the planting of 94 acres widgeon and eel grass. The SAV beds will also benefit indirectly from the project because the construction of reef habitat and the establishment of a bay scallop population will result in improvements to water clarity, which will positively contribute to the bay-wide effort to increase the health and size of SAV beds within the Lynnhaven System.

The NAA will have no impacts on the SAV resources of the Lynnhaven Basin. The SAV beds may return to the Lynnhaven Basin without assistance; however, the current population is extremely small and may be an inadequate seed source to reestablish the beds to their past dimensions.

As part of the selected plan and the AM of the project, herbicides will be used to control the growth and spread of *Phragmites* at the four wetland sites. The USEPA approved herbicides for *Phragmites* control include one of two active ingredients: glyphosate or imazapyr. Both glyphosate and imazapyre are both broad-spectrum, foliar-applied chemicals. The chemicals do have the ability to kill most green plant tissue that they come in contact with, although Imazapyre does not kill conifers and some wetland shrubs. Both herbicides break down quickly in wet soils, but imazapyre remains active longer than glyphosate. No negative impacts to the existing SAV populations or to the restored population are expected if the herbicides used at the wetland sites are applied using a method prescribed by the manufacturer.

11.1.3 Aquatic Fauna. The construction of the Lynnhaven project may result in potential short-term, negative impacts to the nektonic community. These impacts include injuries and mortality due to direct encounters during placement of reef habitat and restoration of the wetland sites, disruption of normal behaviors, and a temporary decrease in water quality. Fish and other marine fauna could be injured during the placement of hard reef structures as the concrete structures and stabilization mats are lowered through the water column, or when the wetland sites are being altered. Fish, however, are extremely motile and will move out of the area during construction. Mortality to slower moving fauna may result if the organisms are buried under the fish reefs or if the organisms cannot move away from the project site when heavy equipment is being operated. Natural behaviors such as foraging and hunting may be interrupted while project activities occur. Organisms that are able to leave the immediate area may be scared away from the affected sites, but behaviors should return to normal once the construction phase has been completed.

Construction of reef habitat and restoration of the wetland sites may result in a temporary decrease in water quality; specifically, turbidity and the concentration of suspended solids and dissolved nutrients may increase while dissolved oxygen levels and water clarity may decrease. These changes could impact nekton by interfering with the respiration of organisms with gills and predators which hunt by sight. Water quality conditions will quickly return to pre-project levels once construction has been completed.

The construction of reef habitat and restoration of the salt marsh sites may also result in short term impacts to the benthic community which would be both minor and temporary. Benthic invertebrates will be buried during the placement of geomesh mats and hard reef structures. The amount of soft bottom covered by the building materials will depend on the size of the mats used. In areas where 8'X8' mats are placed, approximately 15 percent or 1.59 acres will be covered. Where 9'X6' mats are used, 17 percent or 1.81 acres will be covered. If evenly spaced, approximately 14 feet will separate each eight foot square mat and ten feet will separate the six foot square mats. Benthic organisms at the wetland sites will also be destroyed by construction activities. In addition, benthic populations in areas adjoining project sites may be adversely affected from decreases in water quality that will occur during construction; however, these impacts will only last during the construction phase and normal conditions will return once construction has been completed.

It is anticipated that losses to benthic populations at the wetland and reef sites will be quickly replaced by an alternate benthic community favoring hard substrate (the mats and fish reefs) and the reef habitat will result in increased diversity and biomass. Additionally, benthos have been found to increase in biomass along the edges of hard reef structures and geomesh areas due to the preference of larger mollusks (hard clams in particular, as well as soft clams) for soft substrate bordering harder areas, in particular reef structure (Wells 1957). These areas provide a partial refuge from predators, encouraging clam settlement and survival. Colonization of the hard reef structures will begin immediately after construction has been completed. Species composition on areas not subject to restoration will likely not be affected; though it is expected that biomass per unit area in areas outside reef footprints will go up due to the construction of the reefs. It will take approximately three years for a mature community to become established on the reef habitat (Burke 2010). It is expected that a similar time frame will be required to reestablish the community within the restored wetland sites.

The long term impacts of the project will be positive for the fauna of the lower Lynnhaven River. For example, increasing the amount of SAV beds will benefit aquatic organisms by stabilizing bottom sediment, improving water quality, and providing forage and nursery habitat. Adding reef habitat to the Lynnhaven Basin will benefit aquatic fauna by providing attachment surfaces for benthic egg masses produced by mollusks and fish and for sessile organisms, including oysters. Reef habitat will also provide shelter for fish and mobile invertebrates. The increased productivity resulting from the project may increase the populations of recreationally and commercially valuable finfish and shellfish communities. All of the environmental benefits produced by the implementation of the Lynnhaven Restoration Project have been discussed in detail in a previous section.

The NAA will have no impacts on the aquatic fauna of the Lynnhaven Basin.

11.2 Terrestrial Resources

Three elements of the Recommended Plan (i.e. SAV planting, reef habitat installation, and bay scallop stocking) will occur within subtidal areas of the Lynnhaven River and will not impact terrestrial resources in the short term. The activities involving the wetland sites may have some temporary negative impacts on terrestrial resources. For example, while the wetland sites are being reshaped, the heavy equipment used in the process may scare terrestrial wildlife. Normal behaviors will be disturbed briefly but will return to normal once the initial activity has been completed. At sites where invasive plants will be replaced by a native community, reestablishment of the elements of the wetland community will be gradual, depending on the success of marsh plantings. Another temporary impact to terrestrial resources would result from herbicide overspray. Misdirected herbicide may damage terrestrial plants adjacent to targeted species. Inadvertent damage will be minimized by timing the spraying to correspond with the period during which the native vegetation is dormant and the invasive species are still active.

Long term impacts of wetland restoration on the terrestrial resources of the Lynnhaven Basin will be primarily positive in nature. At the GNS and MDC sites, increasing habitat diversity through the creation of new habitat features will increase the types of wildlife which use the sites. Open shallow pools will encourage wading birds, while building and planting upland islands will attract song birds. The short term possible negative impacts related to the Recommended Plan will be outweighed by the benefits which restored wetlands typically provide.

The NAA will have no impacts on the terrestrial resources of the Lynnhaven Basin.

11.3 Threatened and Endangered Species

The Recommended Plan will have no negative impacts on federally threatened or endangered species or state species of concern. The proposed project will affect tidal salt marshes and shallow subtidal areas within the Lynnhaven Basin. The listed species documented as occurring or potentially occurring in the project area, described in length in Section 2.5 of this report, include five sea turtle species, one terrestrial bird, and three shore birds. The terrestrial bird, the red-cockaded woodpecker, inhabits forested areas. The piping plover is associated with sandy beaches and does not utilize habitat types found at the proposed project sites. The roseate tern is a marine species that nests in colonies and plunge dives for fish. This bird could possibly use the subtidal sites as feeding grounds; however, this species prefers open ocean habitats. The Red Knot is a transient species which is known to fly through the project area in order to reach the species' major North Atlantic staging areas located in the Delaware Bay and Cape May Peninsula. While sea turtles may forage in the proposed project area, they are highly mobile and would be able to avoid impacts due to construction. One of the primary benefits of the Lynnhaven Restoration Project is the increase in secondary production, resulting in larger populations of prey items for sea turtles and shore bird species that utilize the project area.

The NAA would have no effect on threatened or endangered species because no threatened or endangered species were found in the project area.

11.4 Essential Fish Habitat

The 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act require Federal action agencies to consult with the NMFS regarding the potential effects of their actions on EFH, which is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. AN EFH Assessment was completed and submitted to NMFS. All adverse impacts are determined to be short-term during contruction, localized, and minimal. EFH coordination is ongoing and no issues are anticipated.

11.4.1 <u>Description of Proposed Action</u>. See the Plan Description Section.

11.4.2 <u>Analysis of the Effects</u>. Appendix C, the Environmental Appendix, includes a description the 19 species in the vicinity of the project and at which life stage the NMFS has determined that those species would come in contact with project elements. A number of the EFH species, such as the clearnose skate, winter skate, Atlantic sea herring, and dusky shark, are not found in the Lynnhaven system and would not be impacted by the project. Other species, including the black sea bass and sand bar shark, have individual life stages that will enter estuarine waters and, therefore, short term impacts caused by the Lynnhaven project would only impact these species if the impacts coincided with the life stage. The last group of fish, including bluefish and Spanish mackerel, utilize estuarine waters throughout their entire life cycle, so negative impacts to the environment resulting from the project no matter when they occurred during the year would impact these species.

Most potentially adverse effects to EFH fish species that are expected to result from the implementation of the Lynnhaven project are minor and short term in their duration.

11.4.2.1 ***Scallop and SAV Restoration*** - No negative impact, either short or long term would result from the restoration of SAV beds or the native scallop population within the Lynnhaven Basin. Numerous positive effects could be realized for EFH fish species, including increased prey populations, bottom sediment stabilization, and improved water quality.

11.4.2.2 ***Wetland Restoration*** - The wetland restoration efforts will occur in the intertidal zone and will not directly impact EFH fish species, but may have an indirect effect on these species. While restoration efforts are occurring, water quality may decrease due to earthmoving and the exposure of sediment. Open marsh areas will be revegetated, and BMPs will be employed to reduce the amount of sediment entering the water column.

11.4.2.3 ***Reef Habitat*** - The construction of reef habitat may result in temporary negative impacts to EFH species similar to those described in the previous section on impacts to the nektonic community. These effects include the disruption of normal activity, injury or mortality from direct contact with hard reef structures and mats during placement, and temporary reduction of water quality. These effects will be eliminated once the construction phase has been completed.

A long term change that will result from the construction of reef habitat is the alteration of sandy bottom habitat to hard reef structure. Currently, the Lynnhaven system consists almost entirely of open sandy or muddy bottom habitat. The uniform bottom type is an artificial remnant of the mismanagement and eventual collapse of the oyster fishery, as almost all of the hard reef structure that was originally present in the system has been lost. This project represents an effort to restore a small fraction of the reef structure to the system. Although some of the preferred habitat type of the sand bar shark that is present within the Lynnhaven system will be altered, large areas of sandy bottom will remain available and the structure added to the system will benefit other EFH species.

In addition to increasing habitat heterogeneity, the new reef structures will produce other long-term benefits. The reef will increase productivity of the system and provide habitat for prey species, such as crustaceans, mollusks, worms and fish. The hard reef structures will provides attachment surfaces for sessile organisms, cover and shelter for many species of fish and other motile invertebrates such as crabs and shrimp, and attachment surfaces for benthic egg masses. Additionally, it is predicted that the reefs will be utilized by oysters, mussels, and other filter feeding organisms, resulting in improved water quality.

11.4.2.4 ***Department of the Army's Views Regarding the Effects of the Action on EFH*** - Adverse effects on species from construction of reef habitat will be temporary and minimal. It is highly unlikely that any adverse effects will be caused by the construction of the hard reef structures due to the nektonic mobility of the EFH designated species. Many studies documenting the effects of turbidity resulting from dredging operations which lasted much longer, indicate that high levels of turbidity and suspended particulate matter at the time of breakwater construction and channel dredging had no lasting detrimental effects on biota near project sites (Van Dolah et al., 1987; Manny et al., 1985).

11.4.3 Discussion of proposed mitigation. No mitigation is proposed for this project because one of the primary goals of this project is to increase the quality and quantity of habitat for fish species that utilize the Lynnhaven River Basin, especially those which depend upon hard reef structure and SAV habitat. The specific benefits gained by the project are described previously in this report.

11.5 Water Quality

Temporary, minor increases in turbidity, dissolved solids, and dissolved nutrients may result from the resuspension of bottom sediments during the placement of fish reefs and mats. Sediment from the salt marsh sites will be exposed during the restoration process and could enter the water column. Increased turbidity has the potential to lower DO. Construction activities will be short-term in nature, so conditions should return to pre-construction levels quickly after the project has been completed. BMPs will be implemented while the wetland sites are being restored and the areas will be revegetated in order to eliminate adverse water quality impacts.

Areas of the Lynnhaven River are listed as impaired for fish consumption due to PCBs. Three of the four elements (SAV planting, scallop reintroduction, and construction of reef habitat) proposed in this project will not impact the bottom sediment. The wetlands measure calls for the removal or relocation of sediment. This material will be tested prior to construction for the presence of contamination. It is unlikely that the sediment at the restoration sites is the source of the PCB contamination found in fish tissue due to the lack of industry, existing or historic, in the Lynnhaven River Basin. However, the release of any sediment into the water column is unwanted and best management practices will be implemented to minimize sediment issues.

A positive result of the Lynnhaven Restoration Project is long term improvement of water quality within the system. SAV beds remove dissolved nutrients from the water column and reduce suspended sediments by stabilizing ocean bottom. The fish reefs will provide attachment sites for sessile filter feeders such as mussels and oysters. These organisms can remove substantial quantities of suspended material from the water column as they feed. For example, a single oyster is reported as being able to filter up to 60 gallons of water a day. Similar to mussels and oysters, Bay Scallops are filter feeders and can filter about 15 liters of water per hour. They also remove suspended solids from the water column, decreasing turbidity, reducing TSS levels, and increasing water clarity. The salt marsh sites will continue to provide the water quality benefits they are currently providing.

The NAA would not change the existing water quality conditions.

11.6 Air Quality

The Lynnhaven Restoration Project lies within the limits of the independent City of Virginia Beach, Virginia. According to the VDEQ Air Regulations (Chapter 20, Section 203), the City of Virginia Beach is designated as a maintenance area with respect to eight hour ozone. The air regulations (9 VAC 5-160 – Chapter 5, section 160) issued by the Virginia DEQ require Federal agencies to prepare a conformity determination if the total of both direct and indirect emissions produced by a Federal action in a maintenance area exceed 100 tons per year of nitrogen, NOx, or volatile organic compounds (VOC).

The most aggressive restoration efforts planned for the wetland sites would require the use of an excavator and a couple of dump trucks. It is estimated that construction efforts would take approximately six months at each site, so 960 hours of equipment use (40 hours over a 4 week period) were used to calculate the air emissions estimate. Using 2008 emissions factors from the USEPA NONROAD model, it was determined that 0.30 tons of VOC and 5.15 tons of NOx would be produced if all three pieces of equipment were operated 40 hours a week over the six month period.

For the SAV plantings and bay scallop stocking, 960 hours and 320 hours were used, respectively, to estimate air emissions. A small boat powered by a single two stroke outboard motor would be necessary to complete both activities. If two boats are used, then approximately 3.8 tons of VOC and 0.2 tons of NOx would be produced to plant the SAV beds, while 1.2 tons of VOC and 0.04 tons of NOx would be released into the atmosphere from the bay scallop stocking effort.

Finally, three pieces of construction equipment were used to calculate air emissions resulting from the placement of concrete fish reefs and stabilization mats, a diesel crane, a small boat powered by a two stroke engine, and a tugboat. It was estimated that 24 months would be required to complete the construction. Therefore, 1920 operational hours (40 hours X 4 weeks X 12 months) were used to calculate emission estimates. Approximately 4.0 tons of VOC and 1.2 tons of NOx per year would be produced in the creation of reef habitat.

The Recommended Plan would have no long term adverse effects on air quality. Minor, short-term effects on local air quality may occur during construction activities associated with the Recommended plan. Short-term health impacts that have been reported caused by air pollution include irritation to the eyes, nose, and through and upper respiratory infections such as bronchitis and pneumonia. Headaches, nausea, and allergic reactions can also result from short-term exposure. Additionally, short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema.

Negative impacts caused by air pollution would be primarily caused by increased emissions of carbon monoxide, hydrocarbons, and nitrous oxides from the operation of the necessary equipment. If all of the proposed construction was performed at the same time, which is not possible due to specific requirements described previously in the report, in total 9.3 tons of VOC and 6.59 tons of NOx would be produced, therefore the Recommended Plan is exempt from making a conformity determination since estimated emissions from construction equipment would be far below the *de minimis* standards of 100 tons/year, which is the minimum threshold for which a conformity determination must be performed.

The NAA would not involve any construction related air emissions, and would, therefore, have no impacts to air quality.

11.7 Noise

Each of the four elements of the Recommended Plan will result in the production of noise while construction takes place. Accurately predicting the levels of noise produced during construction is difficult due to variability of several factors, including the distance from the construction site, vegetation, changes in elevation, temperature, and humidity; however, an estimation of maximum level of noise that could be produced by each action was calculated.

SAV planting and bay scallop stocking will require the use of one to two small boats powered by outboard motors. SAV seeding is estimated to take six months and the stocking of bay scallop will be completed in two months. Although these two activities will take place at the same sites, they will not occur concurrently. The SAV beds must be seeded and given time to become established before the Bay Scallops can be stocked because the mollusks depend upon the SAV habitat. The noise produced by an outboard boat engine depends on the type of motor and how the motor is being run. At idling speeds, an outboard motor can produce between 70 and 75 dBA, but at full throttle, engines can produce between 85 and 90 dBA. During seeding and stocking activities, the boat motors will typically be idling or moving at slow speeds, which will limit the noise produced during the operation.

In total, the construction of reef habitat in the Lynnhaven Basin will take 24 months. The equipment needed to place the hard reef structures includes a crane positioned on a barge, a tow boat to move the barge, and small vessels powered with outboard motors. Decibel levels produced by a crane are approximately 80 to 90 dBA, while a tugboat will produce approximately 80 dBA, and an outboard motor will create between 70 and 90 dBA. If all three pieces of equipment are running at the same time, between 83 and 93 dBA of noise would be produced (NYDEC, 2001).

The restoration and diversification of wetlands sites will require the use of excavation equipment to dig out the top layer of the marsh and trucks to move the material off site at the PA and GNN sites. Approximately six months will be required at each site to complete the restoration efforts. A diesel excavator and two to three diesel dump trucks would be required at sites where excess sediment must be moved off site, while only an excavator will be required at sites where sediment is used onsite. The range of noise produced by various makes and models of dump trucks has been found to be 83 to 94 dBA, while a diesel excavator can produce between 72 to 93 dBA as measured at 50 feet (USEPA, 1971). If all four pieces of equipment are operated at the same time, between 83 and 100 dBA of noise would be produced (NYDEC, 2001).

The noise projections above describe the noise level at the source and do not take into account the factors that affect the noise levels experienced by a receptor. These include the distance from the source, obstacles that block noise such as barriers and buildings, topography, vegetation, and meteorological conditions such as wind direction and speed, temperature and temperature gradient, and humidity. Noise levels decrease as one moves further away from the source. A point source of noise, such as an idling truck or piece of construction equipment, decreases by a rate of six to nine dBA for each doubling of distance from the source. For example, the typical construction site generates 100 dBA of sound, while 500 feet from the source the noise level is reduced to 65 dBA. Noise is also reduced as it passes through buildings. Sound transmission loss through 230 mm brickwork plastered on both sides is estimated to be 55 dBA, while one layer of plasterboard can reduce sound by 25 dBA.

The City of Virginia Beach regulates noise through its Municipal Code, Title 12, Chapter 23, Article II, Noise. The code prohibits noise exceeding 55 dBA during the hours of 10:00 pm and 7:00 am when measured inside a private residence. During the day, noise that can be measured inside a private residence exceeding 65 dBA is prohibited between 7:00 am and 10:00 pm. In addition, certain construction equipment, including cranes, cannot be operated between the hours of 9:00 pm and 7:00 am. In order to comply with the Virginia Beach code, construction machinery would be operated for approximately eight hours, generating noise only during the daytime (7am-6pm) when many residents are at work.

Ambient noise levels will increase while restoration measures are being constructed and may be noticeable by the residents living adjacent to the Lynnhaven system. However, due to the distances from the construction sites to local residences, obstructions between the construction sites and residences, and the sound absorption qualities of buildings, sound levels due to construction will not exceed the Municipal Codes for sound established by the City of Virginia Beach.

The No Action alternative will result in no significant impact on noise levels.

11.8 Hazardous, Toxic, and Radioactive Waste

The measures proposed for the Lynnhaven Basin Restoration Project are not expected to result in the identification and /or disturbance of HTRW. A Phase I investigation of potential HTRW, in accordance with ER 1165-2-132 (USACE, 1992), was completed and is located in the Environmental Appendix. Due to the operational history of the site and the data gathered during the ESA, there is no evidence that HTRW will be found within the wetland sites, when sediment is disturbed during construction.

Even though no HTRW is expected to be encountered, best management practices will be employed during construction at the wetland sites to avoid the suspension of sediment and the release of any contamination into the water column. An erosion control plan will be created and implemented to control the entry of sediments into the tidal streams and their migration downstream of the work area. Construction will occur during low tide when the marsh sites are dewatered to avoid the introduction of sediment into the water column.

Material that is excavated from the wetland sites is considered dredge material and is regulated by the Clean Water Act. The application for a combined permit for the dredging is included in the Environmental Appendix. Once excavated, the sediment will fall into two categories depending on their fate and are regulated by different laws. Material that is used on site to construct habitat features, such as hillocks, is still covered by Section 404(b) Clean Water Act and requires consideration of the potential impacts of the placement of the material, as described in this report. Material that will not be reused on site, but will instead be dewatered and removed to an upland disposal site, is classified as "soil" and is regulated as by the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This sediment will be tested as required for proper upland disposal at a landfill facility. The testing will be completed in the next phase of this project.

No impacts in regards to hazardous contaminants would occur as a result of the NAA.

11.9 Social Impacts

In general, the Recommended Plan would have relatively minor social impacts. The measures involving SAV and scallop restoration are not anticipated to have any direct social effects. The placement of fish reef structures may enhance the recreational fishery as fishing stocks improve from the increased habitat, which would be a positive effect. The sites proposed for partial or total *P. australis* removal will experience some visual changes. For the Princess Anne High School area and at the GNS site, the *P. australis,* which is about ten feet tall, would be replaced with the much shorter *Spartina alterniflora,* which averages three feet. In the other two sites, swaths of the *P. australis* would be removed and replaced with habitat types including open pools and tidal streams that will provide open areas in the reed stands.

The Lynnhaven River is the locus of much recreational fishing. Speckled trout, red drum, flounder, spot, and croaker are the most notable species, and most who fish for them are fishing for food as well as sport. The Virginia Department of Health posted PCB warnings for two species striped bass and gizzard shad in late 2004. For both species the warning recommends no more than from two meals per month. The warning for striped bass covers the Chesapeake Bay and tidal tributaries and the one for gizzard shad is for the Eastern Branch of the Lynnhaven River only. This has not seemed to dampen the enthusiasm of local anglers for this location. In season, the shores of Lynnhaven Park on the south side of the inlet are crowded with anglers fishing. Kayak and boat fishing is common and the Lynnhaven River a favored location for the former. It is also noted as an area for saltwater fly fishing targeting speckled trout. Although most anglers eat what they catch, there is no documented subsistence fishing in the Lynnhaven.

The establishment of reef structures and SAV should increase the stability of sediments, as well as enhance fish habitat. While implementing these features could have some minor short term increase in turbidity, caused by bottom disturbance during construction, the long term effect on fishing would be positive.

Tourism is a leading industry in Virginia Beach. The resort area is widely known and draws regular overnight visitors from across the eastern United States and Canada. Visitors to Virginia Beach spent an estimated $890 million dollars in 2007 with a total economic impact of about $1.44 billion dollars in output from the city's industries, 15,100 jobs, and $378 million dollars in earnings (Yochim and Agarwal 2008: 6). Visitor spending was up to $1.129 billion by 2010 (VBgov.com). Of course the Atlantic Ocean and Chesapeake Bay beaches are the primary attractions for more than 2.7 annual overnight visitors annually (Yochim and Agarwal 2008: 19). Along with swimming, surfing, sunbathing, and fishing, a growing segment of tourists are attracted by eco-tourism, simply viewing and enjoying natural areas. In recognition of this, the City of Virginia Beach included an line for "Nature-Based Visitation Development" and a nature are in its tourism related capital improvement projects in 2007 (Yochim and Agarwal 2008). While Back Bay and First Landing State Park are noted eco-tourism destinations in Virginia Beach, the Lynnhaven River offers an appeal to those who want to experience a salt water estuarine environment. In this regard, the proposed project would have a beneficial effect on tourism.

The plan would not have any adverse effects on population, land use, community cohesion, transportation, or income levels. It would not result in any population displacement or private property acquisition. No permanent effect on employment would occur although project construction would provide employment during the period of construction for some workers. The plan would also provide positive opportunities for environmental education, especially at the Princess Anne High School site, and possibly community involvement.

There would be no social impacts as a result of the NAA.

11.10 Environmental Justice

An analysis of U.S. Census data from 2000 for the tracts that encompass the areas where the selected plan would be located showed that the tracts have a smaller minority population than the city as a whole, 18 percent compared to 29 percent. The percent of population in poverty was slightly higher for the tracts covering the project area than for the city, 6.4 percent compared to 5.1 percent, but this difference is not considered significant. Implementation of the Recommended Plan would not have a disproportionate effect on any minority or low income groups. In view of the fact that the plan would have positive environmental effects with no significant negative effects, project implementation should not have environmental justice issues regardless of the composition of the population in project area.

The NAA would be not cause environmental impacts.

11.11 Cultural Impacts

The expected effects of the Recommended Plan on cultural resources vary, depending on the specific component of the Recommended Plan. The restoration of SAV and scallops is not anticipated to have any effects on cultural resources. The SAV restoration measure which involves simply broadcast seeding of eelgrass and widgeon grass would not affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River. Using mechanical planters to plant SAV would involve only a minor subsurface disturbance of only a few inches of depth as the plants are inserted in the substrate. Similarly, the placement of juvenile scallops, which are about one inch in diameter, in the areas targeted for SAV restoration would not affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River. Therefore, a determination of no effect has been made for the SAV and scallop restoration measures that are parts of the final plan.

The placement of fish reef structures could potentially affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River where these structures would be placed (see Figures 16 and 17). Although there are no records of any significant historical resources in the specific areas targeted for reef ball placement, the settlement patterns of the Lynnhaven River Basin and the use of the river do not preclude the possibility of submerged cultural resources in the areas where the hard reef structures would be placed. Therefore, a remote sensing survey would be carried out for the areas under consideration for placement of hard reef structures in the selected plan during the next phase of this study (the PED phase). Any suspicious targets found in this survey could then be avoided in the actual placement of the hard reef structures.

The *P. australis* removal would affect an area that has traditionally had lower elevations and been wetlands in the first half of the 20^{th} century and probably earlier. The *P. australis* removal measure will involve soil disturbance with the cutting of channels through the areas to facilitate the flow of brackish water and provide a more varied habitat in the areas. No cultural resources have been found previously in these areas. In the case of the PA site, map evidence indicates that the proposed restoration site was previously the location of a sewage treatment/disposal facility. Because of this usage, this area has very likely been previously heavily disturbed, and it is unlikely that significant cultural resources still remain in an undisturbed state. A determination of no effect has been made for any project constructed at this site. For the other three sites (MDC, GNN, and GNS), a Phase I cultural resources investigation will be carried out in the next phase of the study (PED) to determine more definitively the likelihood of there being cultural resources that would be affected by implementation of the selected plan.

This study was initially coordinated with the VDHR by letter of August 4, 2005. Informal coordination by telephone has occurred as the study progressed. Formal coordination will continue through the review phases of the Feasibility Study and during the design phase as the cultural resource field studies are carried out.

No impacts to cultural resources would occur as a result of the NAA.

11.12 Sea Level Change

Data collected by the Sewells Point tide gauge in Virginia was used to project SLC for the Lynnhaven Project. This particular gauge has been collecting tide and sea level change information since 1927. As required by USACE policy (EC 1165-2-212 - Sea Level Change Considerations in Civil Works Programs) increases in sea level were calculated for three different accelerating eustatic SLC scenarios - low, intermediate and high. Sea level is projected to rise by 0.73 feet within fifty years if the rate of increase remains consistent with historic trends as described in the low scenario (Table 28). The intermediate scenario predicted a 1.14 foot increase in the sea level, while the high scenario forecasted that sea level will increase 2.48 feet over the 50 year life span of the project.

The two elements of the Lynnhaven Study that will be most influenced by sea level rise are SAV and wetland restoration, while SLC will have little or no effect on reef habitat and Bay Scallops. Although Bay Scallops prefer SAV habitat, they are also associated with sand and muddy bottoms and will persist without SAV. If the locations of the SAV beds shift due to the effects of SLC, the bay scallop population will adjust with the SAV beds. As sea level rises, the depth of the hard reef structures will increase; however, the fish and invertebrates within the Basin will continue to utilize the structures. SLC may limit the amount of algae that depends on light transmission using the reef habitat.

Table 28. PROJECTED INCREASE IN SEA LEVEL FROM INITIAL CONSTRUCTION, 2014 THROUGH THE 50 YEAR LIFE SPAN OF THE LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT

Year	Low Scenario (ft)	Intermediate Scenario (ft)	High Scenario (ft)
2014	0	0	0
2019	0.07	0.10	0.17
2024	0.15	0.20	0.36
2029	0.22	0.30	0.57
2034	0.29	0.41	0.79
2039	0.36	0.52	1.03
2044	0.44	0.64	1.29
2049	0.51	0.76	1.56
2054	0.58	0.88	1.85
2059	0.66	1.01	2.15
2064	0.73	1.14	2.48

Two recent studies have investigated the impact of SLC on the tidal wetlands of the Virginia Beach area. In the first, the U.S. Climate Change Science Program (Cahoon et al., 2009) assessed wetlands of the mid-Atlantic Region, and the second was completed by VIMS and concentrated specifically on tidal marshes in the Lynnhaven Basin (Berman and Berquist, 2009).

The U.S. Climate Change Science Program study predicted wetland survival using three different scenarios, twentieth century rates of SLC, a 2 mm/yr (0.007 ft/yr) acceleration of SLC, and a 7 mm/yr (0.02 ft/yr) increase (Cahoon et al., 2009). The study concluded that wetlands in the Virginia Beach area would keep pace with increases to ocean levels predicted in Scenario 1, but would not survive and would be converted to open water if sea level increased at the rate described by Scenario 3. The fate of local wetlands could not be determined at the Scenario 2 rate of increase and would be dependent on hydrology and sediment supply.

The VIMS wetland study also assessed SLC at three different rates (Berman, 2009). The most conservative prediction used an increase of 4.1 mm/yr (0.01 ft/yr), a rate similar to the historic SLC observed at the Sewell's Point, VA tide gauge. This scenario predicted increases in sea height by 102.50 mm (0.40 ft) and 205 mm (0.67 ft) at years 2032 and 2057 respectively, resulting in the loss of nearly 30 percent of all wetlands in the Lynnhaven Basin over the next 50 years. Two more aggressive rates, 7.35 mm/yr (0.02 ft/yr) and 17.20 mm/yr (0.06), were used to project SLC out to year 2100. Increases in sea level of 683 mm (2.24 ft) and 1600 mm (5.25 ft) were calculated for the medium and high accelerated rates, resulting in the loss of 95 percent and 100 percent of all wetlands.

The VIMS study did not account for vertical accretion or horizontal transgression; the study concluded that SLC is "clearly a risk to intertidal wetlands" and that virtually all tidal wetlands in the Lynnhaven Basin could be lost. Individually, the wetland sites have different exposures to increasing sea levels. Both the GNS and the MDC sites are impounded behind embankments and are connected to tidal influence by small culverts.

These sites were not even considered tidal wetlands in the VIMS study. It is possible that these sites might be protected from the increase in ocean height, and increased tidal inundation may help the sites revert back to a *Spartina sp.* dominated system. Both GNN and PA are exposed to the full effect of SLC. The VIMS study predicts the complete loss of these sites by 2100 for the two most aggressive predictions of SLC (4.1 mm/yr and 7.35 mm/yr). However, these sites are not completely surrounded by developed and hardened banks. The PA site has a wooded buffer zone between it and the school property, while the GNN site is adjacent to a Phragmites dominated area that is higher in elevation than marsh in the project site. Although the project sites may be lost to SLC, new marsh may expand into the undeveloped surrounding areas.

SAV beds are not static systems and can, to some degree, adjust to meet changing habitats conditions. As the water column becomes deeper due to SLC, aquatic plants will migrate into shallow waters if allowed by the geography and development of the inundated shoreline.

Elements of the Lynnhaven River Basin may limit the ability of the SAV beds to adjust to SLC. A large amount of the Lynnhaven shoreline is developed, consisting of high slopes, hardened shoreline, and structures. This development could hinder the natural movement of SAV beds and stop the natural progression of marine plants into newly inundated areas. Also, eelgrass, *Zostera marina,* is at the southern limits of its range in the Chesapeake Bay. As a result, the effects of climate change on eelgrass populations may be more pronounced that at other sites.

11.13 Cumulative Impacts

The cumulative impact assessment is the evaluation of the effects that other past, present, or reasonably foreseeable future actions, alternatives, or plans might have on the environment when considered along with the proposed project's impacts.

11.13.1 <u>Population Growth and City Development</u>. In 1970, Virginia Beach was a small city, with a population of about 172,000 people. Between 1980 and 1990, the city's population grew at a rate of 50 percent, making it one of the fastest growing cities in the United States. By 1993, the number of people living in Virginia Beach had reached more than 419,000. Through a diverse economy, various development projects, and burgeoning tourism, Virginia Beach became one of the largest cities in Virginia.

Currently, more than 434,000 people reside in the Virginia Beach area. Roughly one-half of the population resides on 1/5 of the city's land mass, in the northern section of the city, which includes the Lynnhaven River Basin. It is predicted that the population surrounding the Lynnhaven system will continue to grow, though not at a pace experienced in the 1980's and 1990's. Growth estimates predict that the population in the Norfolk-Virginia Beach-Newport News MSA will increase by 0.8 percent annually through 2030, while the Virginia Employment Commission projects that the Virginia Beach population will reach more than 490,000 by 2030.

In preparation for continued population growth, the City of Virginia Beach has produced a comprehensive growth plan in order to direct future development of the city (City of Virginia Beach, 2010). For the last 25 years, the city has encouraged growth in the northern region of the city, where the Lynnhaven system is located. City officials have designated strategic growth areas (SGAs) along the Route 264 corridor, west of Rosement Road, and north of Virginia Beach Boulevard. Areas which have been designated as SGAs are slated for concentrated growth in a strategic and sustainable manner, where centers of employment, living, commerce, shopping, arts, and culture will be developed. The SGAs will be modified from their currently undeveloped or suburban patterns into urban areas. Most SGAs are located within the Lynnhaven Basin, so the environmental impacts resulting from the creation of urban areas, such as increased acreage of impervious surfaces and amounts of runoff, will affect the Lynnhaven system.

Water quality in the Lynnhaven Basin deteriorated as Virginia Beach quickly developed into the urban city with surrounding suburban residential neighborhoods. Reduced environmental quality has resulted in the loss of almost the entire SAV population within the estuary. Additionally, elevated bacteria levels within the Lynnhaven River forced the Virginia Health Department to close almost all of the shellfishing grounds within the system for decades, and the area was included on the section 303(d) list of impaired waters due to fecal coliform concentrations (USEPA, 2009).

Over the last ten years, significant environmental improvements to the Lynnhaven system occurred due to partnerships between the City of Virginia Beach, motivated grassroots organizations, such as Lynnhaven River NOW and The Chesapeake Bay Foundation, and state and Federal agencies. In 2006, Virginia Department of Environmental Quality (DEQ) completed a TMDL for fecal coliform for the Lynnhaven River, with ultimate goal of meeting bacteria water quality standards in order to support "the production of edible and marketable natural resource" designated use. The TMDL implementation plan included sanitary sewer improvements, stormwater programs, boat programs, and pet waste programs. Local groups have worked together to implement the TMDL plan through increased public awareness, improvements to infrastructure, and changing city ordinances, all in an effort to restore the estuary to its former glory (USEPA, 2009).

Actions which have been taken to reduce the amount of bacteria entering the system include designating the Lynnhaven River as a No Discharge Zone, which prohibits the discharge of sanitary waste from boats, and offering a free summer boater pump out service (Lynnhaven River NOW, 2009). The City of Virginia Beach has also spent $45 million to reduce the number of sewer leaks and overflows into the river. The city has attempted to eliminate septic tanks within the Basin. Of the 11,600 septic tanks that were originally in the system, only 238 tanks remained in 2009.

Since the implementation of the TMDL, ongoing efforts have resulted in reduction of fecal coliform levels and the restoration of healthy shellfishing areas (USEPA, 2009). In late 2007, the Virginia Department of Health opened 1462 acres (29 percent) of the Lynnhaven to shellfish harvest, which included some areas for the first time since the 1930's. By 2009, a total of 1934 acres met the rigorous bacteria standard for safe shellfish harvest and were opened to shellfishing.

Stormwater entering the Lynnhaven River plays a pivotal role in the degraded water quality within the system. At present, stormwater enters the Lynnhaven River through approximately 1,000 stormwater outflows (Lynnhaven River Now, 2009). Most of the runoff, which contains materials such as pesticides, nutrients, pet waste, and petroleum products, is not treated before it enters surface waters of the Lynnhaven River.

Recently, stormwater management has improved in the Lynnhaven system. The City of Virginia Beach has installed a new filtration system and continues to use solar aeration to remove bacteria, sediment, and nutrients from stormwater; however, only 19 percent of stormwater is currently being treated before it enters the Lynnhaven system (Lynnhaven River Now, 2009). The Green Ribbon Committee of Virginia Beach has created new strategies for the management of stormwater, including support of low impact development, prohibiting direct discharges into wetlands, revisions to storm sewer discharge ordinances, and defining a city-wide minimum water quality standard. Once these strategies are implemented, it is expected that the amount of stormwater that receives treatment will increase. Additionally, in 2009 the city allocated another $1.2 million for the development of a Comprehensive Stormwater Management Plan and a new bacterial tracking method.

Although improvements to some elements for water quality have been observed, it is foreseeable that water quality will remain an ongoing challenge in the Lynnhaven River (Lynnhaven River Now, 2009). Each year, Lynnhaven River NOW, a private, environmental organization dedicated to the restoration of the Lynnhaven River, rates the system on many criteria including water quality. The most recent report, completed in 2009, noted that bacterial contamination, from human, pets, and wildlife fecal material, is still a large problem in the river. Dissolved nutrients, specifically nitrogen and phosphorus used in lawn and garden fertilizers, are continuing to enter the system in large quantities via stormwater runoff. Also in 2009, 7.9 mi^2 of the Lynnhaven River was classified as impaired due to low levels of dissolved oxygen. Finally, water clarity within the Lynnhaven River, due to elevated levels of suspended solids and algae, remains low enough to limit the distribution and restoration SAV.

11.13.2 Native Oysters. The current diminished population of native oysters within the Lynnhaven system is the direct result of past harvesting practices, disease, and degraded habitat quality. Harvesting oysters is destructive to the reef because oyster shell, which makes up the reef structure, is removed from the shellfish bed. Historically, shell material was not replaced, resulting in the loss of oyster habitat. In addition to habitat destruction, disease and overharvesting damaged impacted oysters to a point where the population could not keep pace with mortality. Oyster beds also suffered from the effects of decreased water quality specifically, increased sedimentation.

Public attention has recently focused on restoring native oyster reefs to the Lynnhaven River. Ten years ago, the Lynnhaven oyster population was estimated to be only 1 percent of historic abundance, but a recent estimate suggests that the current population has grown to approximately ten percent of historic numbers. The Norfolk District, USACE has played a large role in the restoration of native oyster populations through the construction of 58 acres (out of a total of 63 constructed in the River) of new sanctuary oyster reefs in the Lynnhaven, building 28 acres of reef in 2007, and constructing an additional 30 acres of new sanctuary oyster reefs in Broad Bay and Linkhorn Bay in 2008. Oyster populations have also been increased through oyster gardening efforts of local residents and the oyster shells saving programs, which return shells to sanctuary reefs. Other cooperative projects between Chesapeake Bay Foundation, the VMRC and the City of Virginia Beach have also resulted in the creation and seeding of reefs within the Lynnhaven River.

Overall, the majority of the reefs constructed by the USACE have been successful according to new Federal standards developed to support EO 13508. To be considered "minimally successful" at least 15 oysters of multiple age classes per square meter of restored reef should be present, and "successful" requires a minimum of 50. The majority of the USACE reefs have well over 50 oysters of multiple age classes per square meter of restored reef according to a survey conducted in winter 2012 and additionally, lots of "spat" (young-of-the-year) oysters were noted on most reefs, indicating continued recruitment of oysters and long-term sustainability of the reef structure.

11.13.3 Sea Level Change. Sea level rise is predicted to have significant negative impacts on the wetlands of the Eastern seaboard, including those within the Lynnhaven system. In a study completed by VIMS, (Berman and Berquist, 2009) it is estimated that if ocean levels continue to rise at historically recorded rates (4.1 mm/year), approximately 81 acres of wetlands will be lost by 2057. The worst case scenario (17.2 mm/year) that was analyzed during the study predicted that all wetland acreage would be inundated by sea water by 2100.

As discussed in an earlier section of this report, wetlands can accommodate an increase in water level of about 3.0 mm/year through vertical accretion, and the wetlands in the Lynnhaven system have kept up with increases of approximately 4.0 mm/year. Wetlands can also adjust to sea level rise by horizontal transgression or moving into upland areas as they become inundated. Developed shorelines, which contain bulkheads, riprap, and other forms of shoreline development, act as barriers which do not allow marshes to move with sea level. The ability of wetlands within the Lynnhaven system to move horizontally will be limited due to the amount of shoreline development. Of the 429 kilometers of shoreline in the system, wetlands are present along 205 kilometers, and 175 of those kilometers are associated with development.

Coastal management will play an important role in controlling the amount of wetland acreage ultimately lost to sea level rise. If soft structural stabilization and living shoreline approaches are supported over hard structures, losses of wetlands may be reduced. The future use and management of the remaining undeveloped land in the Basin will also be important for the preservation of wetlands. Setting aside open areas will provide a corridor that will allow wetland migration in the future.

11.13.4 Conclusion. The future will contain both continued challenges and improvements for the ecosystem of the Lynnhaven Basin. Population increases within the surrounding Basin and the development of the city towards an urban center will place added environmental stressors on an estuary. However, the City of Virginia Beach and other non-government organizations are motivated to restore the health and function of area, and significant strides have been taken to address the significant environmental issues affecting the system. These organizations will continue to implement programs towards the achievement of their long term goals of restoration. The proposed Lynnhaven River Basin Restoration project will complement their continuing efforts within the watershed. For example, one of the goals of Lynnhaven River Now is to establish 175 acres of SAV. The Lynnhaven River Basin Restoration project will both assist in the achievement of this objective directly, by seeding 90 acres of SAV beds, and indirectly, by improving water quality through establishment of reef habitat and the sessile filter feeders that will populate the reef structure.

Under a no action plan, none of the project elements will be constructed in the Lynnhaven system. Efforts by other organizations will continue to benefit water quality and ecosystem productivity. However, the improvements to the river will continue at a much slower pace than could be expected with project which so complement to their efforts.

11.14 Environmental Laws, Statutes, Executive Orders, and Memorandum

1. Archaeological and Historic Preservation Act of 1974, as amended, 16 U.S.C. 469 et seq.

Compliance: Draft report was submitted to the VDHR for comment. Continued coordination with VDHR, where required, signifies compliance.

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

Compliance: Submission of this report to the Regional Administrator of the USEPA for review pursuant to Sections 176 (c) and 309 of the Clean Air Act signifies compliance. Although the proposed project is located in Virginia Beach, Virginia, which currently is in nonattainment (marginal) for ozone, a formal conformity determination is not required due to emissions not exceeding regulatory thresholds.

3. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972 and Water Quality Act of 1987) PL 100-4, 33 U.S.C. 1251 et seq.

Compliance: A Section 404(b)(1) Evaluation and Compliance Review has been incorporated into this report. VMRC and Virginia Beach Wetlands Board permits will be acquired via Virginia's joint permit application (JPA) process. USACE has been and will continue to coordinate with DEQ as the project moves forward. A 401 Water Quality Certification will be obtained from the Division of Water prior to construction.

4. Coastal Barrier Resources Act.

Compliance: The project is not located within the Coastal Barrier Resources System (CBRS) or in an Otherwise Protected Areas (OPA).

4. CZM Act of 1972, as amended, 16 U.S.C. 1431 et seq.

Compliance: In accordance with the Coastal Zone Management Act (CZMA) and the approved Coastal Zone Management Program of Virginia, the proposed project has been evaluated for consistency with the coastal development policies. A consistency determination has been submitted to VDEQ. USACE has determined that the construction of the project is consistent to the maximum extent practicable with the enforceable policies of the Virginia Coastal Zone Management Program.

5. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

Compliance: Review of databases and coordination with USFWS and NFMS produced no formal consultation requirements pursuant to Section 7 of the Endangered Species Act.

6. Estuarine Protection Act, 16 U.S.C. 1221 et seq.

Compliance: Coordination of this document with appropriate Federal and state resource agencies signifies compliance with this act.

7. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq.

Compliance: Coordination with the National Park Service and the VDCR, relative to the Federal and state comprehensive outdoor recreation plans, signifies compliance with this act.

8. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.
Compliance: Coordination with the USFWS, NMFS, and VDGIF signifies compliance with this act. Coordination Act comments have been included in correspondence from USFWS (Appendix E).

9. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq.

Compliance: Coordination is not required because the proposed project does not involve an undertaking that will or may affect properties of facilities acquired or developed with the assistance from this Act..

10. Marine Protection, Research, and Sanctuaries Act of 1972, as amended 33 U.S.C. 1401 et seq.

Compliance: Not applicable; project does not involve the transportation or placement of dredged material in ocean waters pursuant to Sections 102 and 103 of the Act, respectively.

11. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 432 et seq.

Compliance: Preparation of this report and public coordination and comment signify partial compliance with National Environmental Policy Act (NEPA). Full compliance is noted with the signing and issuing of the Finding of No Significant Impact.

12. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

Compliance: Coordination with the VDHR and agency concurrence with the findings of this report signify compliance with this act.

13. Rivers and Harbors Appropriation Act of 1899, as amended, 33 U.S.C. 401 et seq.

Compliance: Exempt.

14. Watershed Protection and Flood Prevention Act, as amended, 16 U.S.C. 1001 et seq.

Compliance: No requirements for USACE activities.

15. Wild and Scenic Rivers Act, as amended, 16 U.S.C. 1271 et seq.

Compliance: The proposed project would not adversely impact any component of the Virginia Scenic Rivers System. Coordination with the National Park Service and the VDCR, relative to the Virginia Scenic Rivers System, signifies compliance with this act.

16. Resource Conservation and Recovery Act. 42 U.S.C 6901 et seq (1979)

Compliance: During the next phase of the project, sediments removed from the wetland restoration sites will be tested to determine if they meet the standard of a "Hazardous Waste." If they are such materials, then handling of the material will comply with all guidance within the law.

Executive Orders

1. Executive Order 11988, Floodplain Management, 24 May 1977, as amended by Executive Order 12148, 20 July 1979.

Compliance: Although, the proposed project is located in the flood plain, it would not result in adverse effects and incompatible development in the flood plains. Circulation of this report for public review fulfills the requirements of EO 11988, Section 2(a)(2).

2. Executive Order 11990, Protection of Wetlands, 24 May 1977.

Compliance: This project has minimized "the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands." Circulation of this report for public review fulfills the requirements of EO 11990, Section 2(b).

3. Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, 4 January 1979.

Compliance: Not applicable, this project is located within the U.S.

4. Executive Order 12898, Environmental Justice in Minority Populations and Low-Income Populations, 11 February 1994.

Compliance: No impacts are expected to occur to any minority or low income communities in the project area.

5. Executive Order 13508, Chesapeake Bay Protection and Restoration, 12 May 2009.

Compliance: The project will contribute to the goals and objectives of the EO

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Executive Memorandum

1. Analysis of Impacts of Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980.

Compliance: The project does not involve or impact agricultural lands.

11.15 Draft Finding of No Significant Impact

FINDING OF NO SIGNFICANT IMPACT
LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT
VIRGINIA BEACH, VIRGINIA

I have reviewed and evaluated the Environmental Assessment (EA) for this project in terms of the overall public interest. The overall purpose of the Lynnhaven River Basin Ecosystem Restoration Project is to provide ecosystem restoration and protection for the water resources of the Lynnhaven River Basin as authorized by the Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted on May 6, 1998. The Recommended Plan and the No Action Alternative (NAA) were the only alternatives carried forward for detailed evaluation. The Recommended Plan includes four elements: the construction of 31 acres of reef habitat, restoration of 94 acres of Submerged Aquatic Vegetation (SAV), re-establishment of a population of Bay Scallops, and restoration of 38 acres of tidal salt marshes.

The Norfolk District has taken reasonable measures to assemble the known or foreseeable impacts of the project in the report. The possible consequences of the Recommended Plan and NAA were considered in terms of probable environmental impact, social well-being, and economic factors. This report presents the impacts that could potentially result from restoration efforts. All adverse effects of project implementation are considered insignificant and are temporary in nature.

The environmental impacts of the project were not found to be significant. There will be some loss of benthic organisms during the construction of the reef habitat and excavation at the wetland sites; however, the losses will be minor and will not affect the benthic community as a whole. Some water quality impacts are expected during the construction phase, but the impacts will be short in duration and minor in scope.

No expected adverse effects on threatened and/or endangered species and/or species of special concern are foreseeable with project implementation. However, monitoring measures and other precautions will be put in place if advised by the National Marine Fishery Service (NMFS) in order to avoid jeopardizing the continued existence of threatened and/or endangered species. Endangered Species Act, Section 7 consultation, may be undertaken and will conclude with a NMFS Biological Opinion.

The proposed project has been evaluated under the Clean Air Amendments of 1990. Due to the small amount of construction required for the completion of the project, the amounts of nitrogen oxides (NOx) and volatile organic compounds (VOC) are not expected to exceed the *de minimus* emission threshold that triggers the requirement to conduct a full-scale conformity determination. The project will comply with Section 176 (c) of the Clean Air Amendments of 1990.

No significant economic or social well-being impacts that are both adverse and/or unavoidable are foreseen as a result of the proposed action. The project will not have any impact on known sites of known significant archeological or historical importance. Further surveys will be carried out to confirm this.

The other project alternatives were not selected, as they had a greater cost per unit benefit to reach the desired project goals. The NAA would not provide any improvement to the environmental condition of the Lynnhaven River Basin.

The conclusions of this report are based on an evaluation of the effects that the proposed action would have on the entire ecosystem, including the land, air, and water resources of the Lynnhaven River Basin. Cumulative impacts of other activities were also considered in this evaluation. Implementing the Recommended Plan would not have a significant adverse effect on the environment. Design features and best management practices that will minimize adverse impacts will be incorporated into the project. The effect of the proposed action will not be environmentally controversial.

The long-term benefits to the ecosystem of the Lynnhaven River Basin will be positive as a result of project implementation. The number of local SAV beds and the amount of reef habitat will be increased. A population of Bay Scallops will be reintroduced into the system and a number of wetland sites will be restored to improve the environmental function.

Due to the absence of significant adverse environmental impacts, an Environmental Impact Statement will not be required.

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Date

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PAUL B. OLSEN, P.E.
Colonel, Corps of Engineers
Commanding

12.0 CONCLUSIONS

The ecosystem problems and needs of the study area have been reviewed and evaluated with regard to the overall public interest and with consideration of engineering, economic, environmental, social, and cultural concerns. The conclusions of this study are as follows:

a. The Lynnhaven River Basin is in a stable but degraded state and will continue in its present condition without any restoration activities.

b. The Recommended Plan consists of 94 acres of submerged aquatic vegetation restoration, 38 acres of wetlands restoration, 31.5 acres of reef habitat restoration, and 22 acres for reintroduction of the bay scallop.

c. The Recommended Plan is feasible based on environmental, engineering and economic criteria and is acceptable by environmental, cultural, and social laws and standards.

d. The selected plan is supported by the non-Federal sponsor, the City of Virginia Beach. The sponsor has the capability to provide the necessary non-Federal requirements identified and described in report Section 11.2, Division of Plan Responsibilities.

13.0 RECOMMENDATIONS

I have considered all significant aspects in the overall public interest which included environmental, social, and economic effects; and engineering feasibility. In view of these considerations, and the conclusions presented above, I recommend that the Lynnhaven River Basin ecosystem restoration be implemented in accordance with the National Ecosystem Restoration plan (the NER Plan), with such modifications as in the discretion of the Commander, HQUSACE, may be advisable, at an total estimated first cost of $34,413,000, with a total first cost to the United States estimated at $22,368,000.

The recommended NER plan involves a combination of restoring submerged aquatic vegetation, reef habitat, reintroduction of Bay Scallops, and wetland restoration and diversification at four different sites throughout the river system.

This recommendation is subject to the non-Federal sponsor agreeing to comply with all applicable Federal laws and policies and other requirements including but not limited to:

a. Provide 35 percent of total project costs as further specified below:

    1. Provide the required non-Federal share of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;

    3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project;

    4. Provide, during construction, any additional funds necessary to make its total contribution equal to 35 percent of total project costs;

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the

Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

c. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

d. Shall not use the project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project;

e. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

f. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

g. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

h. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

i. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

j. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

k. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

l. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

m. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

n. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

Federal participation in the recommended project is endorsed provided that, prior to construction, the non-Federal sponsor will execute the final Project Partnership Agreement with the Federal Government.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to higher authority as proposals for authorization and implementation funding. However, prior to transmittal to higher authority, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

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FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

Appendix A

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION

VIRGINIA BEACH, VIRGINIA

U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510-1096

July 2013 modified February 2014

APPENDIX A

ENGINEERING, DESIGN, AND COST ESTIMATES

APPENDIX A

ENGINEERING, DESIGN, AND COST ESTIMATES

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INTRODUCTION

This Engineering Appendix outlines the engineering and design work to support the preparation of the Lynnhaven River Basin Environmental Restoration, Virginia Beach, Virginia.

Background

The study area covers the entire 64 square mile drainage area of the Lynnhaven River Basin which contains mostly developed neighborhoods and shopping centers. The Lynnhaven River complex, which includes the mainstem, the Eastern Branch, the Western Branch, and Broad Bay/Linkhorn Bay, is located in the city of Virginia Beach, along the southern shore of the Chesapeake Bay, between Cape Henry and the city of Norfolk.

The Lynnhaven River is the largest tidal estuary in the city and lies in the heart of the urbanized northern half of the city. This resource has 150 miles of shoreline and hundreds of acres of marsh, mudflat, and shallow water habitats. The river supports a tremendous level of recreational boating and fishing, crabbing, ecotourism, and general environmental observation. The navigational needs of the residents and users of the river are an integral part of the river's attraction. However, the river has become increasingly stressed over the past 30-plus years, as the watershed has experienced a shift from a predominantly rural to a predominantly urban/suburban land use pattern. This conversion has subjected the river to the expected accompanying development pressures related to the concurrent loss of natural buffers and increases in population and density.

Project Objective

The project objective is to develop a National Ecosystem Restoration (NER) Plan that reasonably maximizes environmental restoration benefits compared to costs, consistent with the Federal objectives. The selected plan will be shown to be cost-effective and justified to achieve the desired level of output.

HYDRODYNAMIC AND WATER QUALITY MODELING

Biological, topographical, and hydrological data were collected (as well as laboratory experiments) and used to support the development of a hydrodynamic and water quality model used to characterize existing conditions and model the future-without-project scenarios as well as future-with-project scenarios. The numerical modeling framework involves an integrated approach that combined several different processes such as hydrodynamic, water quality, nutrient, sediment processes in order assess nutrient load reductions for the Lynnhaven River system. Whereas the CE-QUAL-ICM (Corps of Engineers integrated compartment water quality model) is the central processing model, it depends, heavily upon the other models with which it interacts, such as the UnTRIM (Unstructured Tidal, Residual, and Intertidal Mudflat) hydrodynamic model for mass and volume transport, the HSPF (Hydrological Simulation Program – FORTRAN) watershed model for freshwater discharge and nutrient loadings, and the sediment model for sediment flux information.

The hydrodynamic model UnTRIM was used in this study as well as an ecological benefits model described in Chapter 9 of the main report. UnTRIM is a semi-implicit, finite difference (volume) model based on the three-dimensional shallow water equations as well as on the three-dimensional transport equation for salt, heat, dissolved matter, and suspended sediments. UnTRIM is governed by the equations of motion, the equation of continuity, and the transport equation. The model is intended to develop a methodology to assess the impact of proposed restoration plans, including Sub-Aquatic Vegetation (SAV), scallops, and fish reefs (including oyster reefs), on the Total Suspended Solids (TSS) and chlorophyll levels near these restoration sites. Final results of the modeling efforts are included in attachments 1 and 2 to this appendix.

SURVEY DATA

Hydrographic survey data was collected within the study area as part of the USACE Federal Navigation Channel maintenance in addition to the specific bathymetric surveys that was carried out in potential restoration areas. Topographic elevations were obtained from LiDAR data processed into a DEM provided to the Corps by the study Sponsor. All surveys are referenced to North American Datum (NAD) 1983 for horizontal and North American Vertical Datum (NAVD) 1988 for vertical elevations.

FLOOD RISK

The coastal areas of Virginia Beach are vulnerable to tidal flooding from major storms commonly referred to as hurricanes and northeasters. Both types of storms produce winds that push large volumes of water against the shore. Hurricanes, with their high winds and heavy rainfalls, are the most severe storms that hit the area. The term "hurricane" is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean just north of the equator. A study of the tracks of all tropical storms for which there is a record indicates that, on an average of once a year, a tropical storm of hurricane force passes within 250 miles of the area and poses a threat to Virginia Beach. While hurricanes can affect the area from May through November, nearly 80 percent occur in the months of August, September, and October, with approximately 40 percent occurring in September. The most severe hurricane to strike the area occurred in August 1933. Other notable hurricanes that caused significant flooding in Virginia Beach were those of September 1933, September 1936, September 1960 and Hurricane Isabel 2003.

Another type of storm that can cause severe damage to the city is the northeaster. This is also a cyclonic-type storm and originates with little or no warning along the middle and northern Atlantic Coast. Northeasters occur most frequently in the winter, but can occur at any time. Accompanying winds are not of hurricane force, but are persistent, causing above-normal tides for long periods of time. The March 1962 northeaster was the worst to hit the study area. Other northeasters that caused significant flooding in Virginia Beach include those of March 1927, October 1948, April 1956, and November 2009. The depth of flooding during hurricanes and northeasters depends upon the velocity, direction, and duration of the wind; the size and depth of the body of water over which the wind is acting; and the astronomical tide. For instance, strong and persistent northerly and easterly winds will cause flooding of the shorelines of the Chesapeake Bay, the Atlantic Ocean, and their connecting inland waterways. Flooding in the Back Bay and North Landing River areas is caused by strong winds from a southerly direction. As would be expected, because of the larger size of the water bodies involved, flooding along the shorelines of the Chesapeake Bay, the Atlantic Ocean, and the Elizabeth River occurs in greater depth than flooding in the southern portion of the city.

Simultaneous flooding of both the outer coastal areas and southern bay areas of the city does not occur except in rare events when the surge-producing forces cause either the destruction or overtopping of the barrier dunes that separate the Atlantic Ocean from the inland waters in the southern portion of the city. The duration of the flooding depends upon the duration of the tide producing forces. Floods caused by a hurricane are usually of much shorter duration than the ones caused by a northeaster. Flooding from hurricanes rarely lasts more than one tidal cycle, whereas flooding caused by northeasters can last several days, during which the most severe flooding takes place at the time of the peak astronomical tide. The timing or coincidence of the maximum storm surge with the normal high tide is an important factor in the consideration of flooding from tidal sources. Tidal waters in the study area normally fluctuate twice daily about 3 feet in the Atlantic Ocean and approximately 2 feet in the Lynnhaven River. The range of fluctuations is somewhat less in most of the connecting interior waterways. There are no measurable astronomical tides in Back Bay or the North Landing River that is minimally connected hydraulicallywell to the south of this study. Flooding can occur as a result of an intense rainfall produced by local summer thunderstorms, or tropical disturbances, such as hurricanes, that move into the area from the Gulf of Mexico or Atlantic Coast. Flood heights on these streams can rise from normal to extreme flood peaks in a relatively short period of time. The duration of flooding depends on the duration of runoff producing rainfall. In some cases, floods may last for a couple of days, whereas floods occurring as a result of short duration summer thunderstorms usually rise to a maximum peak stage and subside to near normal levels in less than a day. The following table lists tidal flood elevation values from the Lynnhaven River flood insurance study.

Table 1. SUMMARY OF STILLWATER ELEVATIONS (NAVD 88)

LOCATION	10 Percent	2 Percent	1 Percent	0.2 Percent
LYNNHAVEN BAY	4.9	6.2	6.8	8.2
LYNNHAVEN RIVER	4.9	6.2	6.8	8.2
BROAD BAY	4.3	5.4	5.9	7.1
LINKHORN BAY	4.3	5.4	5.9	7.1

All of the alternatives considered in the study have the potential to be impacted by intense storm events such as hurricanes or northeasters. The degree of damage and the length of recovery time depend mainly on the duration, magnitude and direction of wind-driven waves. The probability of complete habitat loss for each alternative is relatively low because the wetlands are located in sheltered creeks or protected with riprap. The most likely damage would come from "rack" debris covering wetland plants. Storm impacts to the reef habitat sites are not considered significant because these sites are submerged under several feet of water. The SAV sites are susceptible to storm wave degradation; however these areas should recover after several growing seasons.

Tides

Tides in the Lynnhaven have been extensively studied and sufficient data exists to describe the general tidal pattern in the estuary. The tidal range reported at the Chesapeake Bay Bridge Tunnel north of the inlet in Chesapeake Bay, is approximately 3 feet. The range reported for Lynnhaven Inlet is 2 feet as this constricted inlet controls tides throughout the basin, which are generally 2 feet or less. Tidal data assembled by the Virginia Institute of Marine Science shows that the Long Creek Channel project of the mid-1960's was successful in achieving its goal of increased tidal flushing of Broad and Linkhorn Bays. These increases were predicted fairly accurately by the USACE study of 1952 (presented in USACE 1962), using fixed and movable bed models. Tidal amplitude has increased in Broad Bay from 0.2 feet to 0.95-1.2 feet, and in Linkhorn Bay from 0.2 feet to 1.01-1.3 feet. Additionally, the phase lag between tides at the inlet and in the bays has been reduced some 2 hours in Broad Bay and 1.5 hours in Linkhorn Bay. Tidal amplitude in the East and West Branches was measured as 2.1 and 1.95 feet, respectively, in 1947, and as 2.0 and 2.0 feet in 1973; this is not a significant change. Virginia Institute of Marine Science, reports that tide ranges are fairly uniform in the branches, even in upstream reaches. Mean tide ranges in the vicinity of the Lynnhaven River are listed below.

Table 2. TIDE RANGES (ft) IN THE VICINITY OF THE STUDY AREA

Location	Tide range
Chesapeake Bay Bridge Tunnel	2.55
Lynnhaven Inlet	2.22
Broad Bay Canal	1.38
Long Creek	1.68

*NOAA Tide Chart

Sea Level Rise. Data collected by the Sewells Point tide gauge in Virginia was used to project SLR for the Lynnhaven Project. This particular gauge has been collecting tide and sea level change information since 1927. As required by USACE policy (EC 1165-2-211 - Incorporating Sea-Level Change Considerations in Civil Works Programs) increases in sea level were calculated for three different accelerating eustatic sea level rise (SLR) scenarios - low, intermediate and high. Sea level is projected to rise by 0.73 ft within fifty years if the rate of increase remains consistent with historic trends as described in the low scenario. The intermediate scenario predicted a 1.14 ft increase in the sea level, while the high scenario forecasted that sea level will increase 2.48 ft over the 50-year life span of the project.

Table 3. PROJECTED INCREASE IN SEA LEVEL FROM INITIAL CONSTRUCTION, 2014 THROUGH THE 50 YEAR LIFE SPAN OF THE LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT

Year	Low Scenario (ft)	Intermediate Scenario (ft)	High Scenario (ft)
2014	0	0	0
2019	0.07	0.10	0.17
2024	0.15	0.20	0.36
2029	0.22	0.30	0.57
2034	0.29	0.41	0.79
2039	0.36	0.52	1.03
2044	0.44	0.64	1.29
2049	0.51	0.76	1.56
2054	0.58	0.88	1.85
2059	0.66	1.01	2.15
2064	0.73	1.14	2.48

The two elements of the Lynnhaven Study that will be most influenced by sea level rise are SAV and wetland restoration, while SLR will have little or no effect on reef habitat and bay scallops. Although bay scallops prefer SAV habitat, they are also associated with sand and muddy bottoms and will persist without SAV. If the locations of the SAV beds shift due to the effects of SLR, the bay scallop population will adjust with the SAV beds. As sea level rises, the depth of the reef balls will increase; however, the fish and invertebrates within the basin will continue to utilize the structures. SLR may limit the amount of algae that depends on light transmission using the reef habitat.

Two recent studies have investigated the impact of SLR on the tidal wetlands of the Virginia Beach area. In the first, the U.S. Climate Change Science Program (Cahoon et al., 2009) assessed wetlands of the mid-Atlantic Region, and the second was completed by VIMS and concentrated specifically on tidal marshes in the Lynnhaven Basin (Berman and Berquist, 2009).

The U.S. Climate Change Science Program study predicted wetland survival using three different scenarios, twentieth century rates of SLR, a 2 mm/yr (0.007 ft/yr) acceleration of SLR, and a 7 mm/yr (0.02 ft/yr) increase (Cahoon et al., 2009). The study concluded that wetlands in the Virginia Beach area would keep pace with increases to ocean levels predicted in Scenario 1, but would not survive and would be converted to open water if sea level increased at the rate described by Scenario 3. The fate of local wetlands could not be determined at the Scenario 2 rate of increase and would be dependent on hydrology and sediment supply.

The VIMS wetland study also assessed SLR at three different rates (Berman, 2009). The most conservative prediction used an increase of 4.1 mm/yr (0.01 ft/yr), a rate similar to the historic SLR observed at the Sewell's Point, VA tide gauge. This scenario predicted increases in sea height by 102.50 mm (0.40 ft) and 205 mm (0.67 ft) at years 2032 and 2057 respectively, resulting in the loss of nearly 30 percent of all wetlands in the Lynnhaven Basin over the next 50 years. Two more aggressive rates, 7.35 mm/yr (0.02 ft/yr) and 17.20 mm/yr (0.06), were used to project SLR out to year 2100. Increases in sea level of 683 mm (2.24 ft) and 1600 mm (5.25 ft) were calculated for the medium and high accelerated rates, resulting in the loss of 95 percent and 100 percent of all wetlands.

GEOLOGY

Soils in the watershed are generally loams and sandy loams, which overlie deep deposits of unconsolidated stratified lenticular sand and silt with some gravel and clay. Soils are easily erodible when cleared of vegetation. Generally, soils are permeable, and Chipman (1948) reports that there is very little surface drainage, and much of the fresh water resulting from rains enters by percolation through the porous subsoils of the banks. As the watershed becomes developed, paved, and ditched, rain waters increasingly enter the estuary as storm water runoff. Stream flow data for tributaries of the Lynnhaven system are unavailable, as there are no gauged streams in the vicinity.

Watershed areas for tributary streams are small, and stream flow is greatly reduced during dry periods. This is evidenced by salinity data, which indicate nearly isohaline conditions throughout the estuary following periods of little precipitation. Generally, salinity increases toward the inlet and decreases in upstream reaches. During hot dry periods, a reverse salinity gradient can develop in the estuary, where, due to evaporation, limited flushing, and low fresh water input, upper reaches may become more saline than areas closer to the inlet. Tidal exchange has increased in Broad and Linkhorn Bays since the completion of the Long Creek project, but it is not clear how the Eastern and Western Branches were affected by these changes.

GEOTECHNICAL INVESTIGATIONS

Norfolk District conducted a subsurface investigation in November 2009 to determine the extent of sandy bottom conditions at various locations throughout the Lynnhaven River system (see Plate 1). Vibracore sampling was conducted from a shallow draft sectional barge utilizing a Trimble Model 132 DGPA unit with submeter accuracy for location determination and a hydraulically operated four point mooring system to position and stabilize the barge while sampling. The vibracore equipment was deployed using a 5,000 lb. capacity hydraulic winch and cable, routed through a 40-foot articulated mast in the middle of the barge. Refer to the following figures for results and boring locations. Samples collected during the subsurface investigation were approximately 10 in length and visually classified according to the Unified Soils Classification System. Boring logs and grain size distribution graphs results are available upon request.

Table 4. SUBSURFACE INVESTIGATION RESULTS

Pt. Num	Pt. Name	X	Y	Lat	Long	Depth of Water	Fines	Sands	Depth to Sand	Bottom MLLW	Sand Elevation	
1	1 as-built	12183762.15	3493581.96	36.89322808	-76.10315105	6.9	2.6 - 3	0 - 2.6; 3 - B.O.H.	3	-5.1	-8.1	
2	2 as-built	12184261.36	3494187.86	36.89480198	-76.10139361	3.6		0 - B.O.H.	0	-1.8	-1.8	
3	3 as-built	12184265.92	3493695.69	36.89350521	-76.10141904	5.2		0 - B.O.H.	0	-3.4	-3.4	
4	4 as-built	12184768.18	3494168.33	36.89476789	-76.09966099	4.6		0 - B.O.H.	0	-2.9	-2.9	HILL POINT
5	5 as-built	12184756.27	3493674.48	36.89341275	-76.09974464	4		0 - B.O.H.	0	-1.8	-1.8	
6	6 as-built	12185264.12	3494179.50	36.89478392	-76.09796463	2.9		0 - B.O.H.	0	-1.4	-1.4	
7	7 as-built	12185273.99	3493794.90	36.89370723	-76.09796435	4		0 - B.O.H.	0	-2.3	-2.3	
8	8 as-built	12185769.47	3494167.88	36.89469669	-76.09623808	3.5		0 - B.O.H.	0	-2.3	-2.3	
9	9 as-built	12185597.63	3493945.82	36.89409899	-76.09684495	5	0.8 - B.O.H.	0 - 0.8	4.2	-3	-7.2	
10	10 as-built	12192188.26	3492931.43	36.89085227	-76.07447239	3.3		0 - B.O.H.	0	-1.8	-1.8	
13	13 as-built	12192962.80	3491808.47	36.88771286	-76.07185514	5.5	0 - 5.6	5.6 - B.O.H.	5.6	-4.4	-10	
14	14 as-built	12193242.30	3491395.96	36.88656049	-76.07093604	4	0 - 1	1 - B.O.H.	1	-3.8	-4.8	
16	16 as-built	12193820.85	3490575.75	36.88428753	-76.06903068	3	2 - 3.5	0 - 2, 3.5 - B.O.H.	3.5	-1	-4.5	
17	17 as-built	12193977.76	3490142.83	36.88306777	-76.06853249	3		0 - B.O.H.	0	-0.2	-0.2	BROCK COVE
19	19 as-built	12193672.91	3491649.14	36.88722520	-76.06944187	4	0 - 1	1 - B.O.H.	1	-2.4	-3.4	
23	23 as-built	12193315.88	3493060.80	36.89112644	-76.07053806	3	0 - 4.5	4.5 - B.O.H.	4.5	-1.8	-6.3	
25	25 as-built	12193810.96	3492353.14	36.88914841	-76.06890801	4	0 - 3	3 - B.O.H.	3	-2.1	-5.1	
26	26 as-built	12194108.12	3491930.78	36.88796772	-76.06782944	3.4	0 - 0.5	0.5 - B.O.H.	0.5	-0.6	-1.1	
29	29 as-built	12194152.29	3493255.02	36.89160056	-76.06766181	1.5	3 - B.O.H.	0 - 3*	0	-0.8	-0.8	3' of sand on top
30	30 as-built	12194469.19	3492790.83	36.89030361	-76.06661944	2	0 - 0.5, 4 - B.O.H.	0.5 - 4*	0.5	-1.6	-2.1	3.5' of sand at 0.5' depth
36	36 as-built	12194082.30	3486939.30	36.87398987	-76.06846607	4	0 - 5	5 - B.O.H.	5	-3.2	-8.2	
39	39 as-built	12194561.90	3486949.52	36.87425858	-76.06681729	3.5	0 - 2.5	2.5 - B.O.H.	2.5	-2.4	-4.9	
40	40 as-built	12194621.21	3486871.57	36.87349120	-76.06663908	3	0 - 4.5	4.5 - B.O.H.	4.5	-1.9	-6.4	
42	42 as-built	12195107.62	3486580.56	36.87320262	-76.06477973	3.5	0 - 7	7 - B.O.H.	7	-1.9	-8.9	BROWN COVE
45	45 as-built	12194932.03	3488041.24	36.87723697	-76.06579787	5.9	0 - 5	5 - B.O.H.	5	-3.6	-8.6	
47	47 as-built	12195429.10	3487664.16	36.87615933	-76.06379052	3	0 - 1.0	1.0 - B.O.H.	1	-0.7	-1.7	
53	53 as-built	12196110.12	3486285.18	36.87232475	-76.06159479	4	0 - 4	4 - B.O.H.	4	-1.1	-5.1	
56	56 as-built	12206236.72	3494021.86	36.89284370	-76.02628460	13.1	0 - 1	1 - B.O.H.	1	-10.6	-11.6	
57	57 as-built	12206350.34	3494928.61	36.89532518	-76.02581495	11.5	0 - 1.4	1.4 - B.O.H.	1.4	-9.6	-11	
58	58 as-built	12206450.58	3494359.23	36.89375461	-76.02552331	12	0 - 3.3	3.3 - B.O.H.	3.3	-9.8	-13.1	
59	59 as-built	12206651.43	3493770.97	36.89212499	-76.02488948	10.5	0 - 4.2	4.2 - B.O.H.	4.2	-9	-13.2	BROAD BAY
60	60 as-built	12206778.23	3494118.87	36.89307107	-76.02442482	11.1	0 - 3	3 - B.O.H.	3	-9.5	-12.5	
61	61 as-built	12206696.50	3494782.28	36.89489846	-76.02464472	12	0 - 1.3	1.3 - B.O.H.	1.3	-9.6	-10.9	
62	62 as-built	12207039.20	3494488.98	36.89408947	-76.02349952	7.5		0 - B.O.H.	0			
P1	P1 as-built	12188143.00	3498134.00	36.90542026	-76.08777760	12		0 - B.O.H.	0			
P11	P11 as-built	12188431.00	3497568.00	36.90384597	-76.08684240	3	0 - 0.4	0.4 - B.O.H.	0.4			
P13	P13 as-built	12188143.00	3497979.00	36.90499468	-76.08779114	4		0 - B.O.H.	0			
P2	P2 as-built	12188187.00	3498049.00	36.90518379	-76.08763459	7		0 - B.O.H.	0			
P3	P3 as-built	12188236.00	3497952.00	36.90491402	-76.08747554	3.3		0 - B.O.H.	0			
P4	P4 as-built	12188212.00	3497825.00	36.90456699	-76.08756869	3.5		0 - B.O.H.	0			PILOT ISLAND
P5	P5 as-built	12188268.00	3498150.00	36.90545542	-76.08734883	3.3		0 - B.O.H.	0			
P6	P6 as-built	12188810.00	3497329.00	36.90316314	-76.08556753	9.2		0 - B.O.H.	0			
P7	P7 as-built	12188684.00	3497593.00	36.90389685	-76.08597523	3		0 - B.O.H.	0			
P8	P8 as-built	12188530.00	3497376.00	36.90331185	-76.08652072	3.6		0 - B.O.H.	0			
P9	P9 as-built	12188803.00	3497916.00	36.90478085	-76.08553995	3.6		0 - B.O.H.	0			
	Hill Point		Brock Cove		Brown Cove		Broad Bay		Pilot Island			

Figure 1. CORE LOCATIONS PILOT ISLAND

Pilot Island As-Built Core Locations
Note: NOAA S57 background chart is approximate, actual core locations plotted
Grid System: NAD83, VA South State Plane, US Survey Feet

Pilot Island

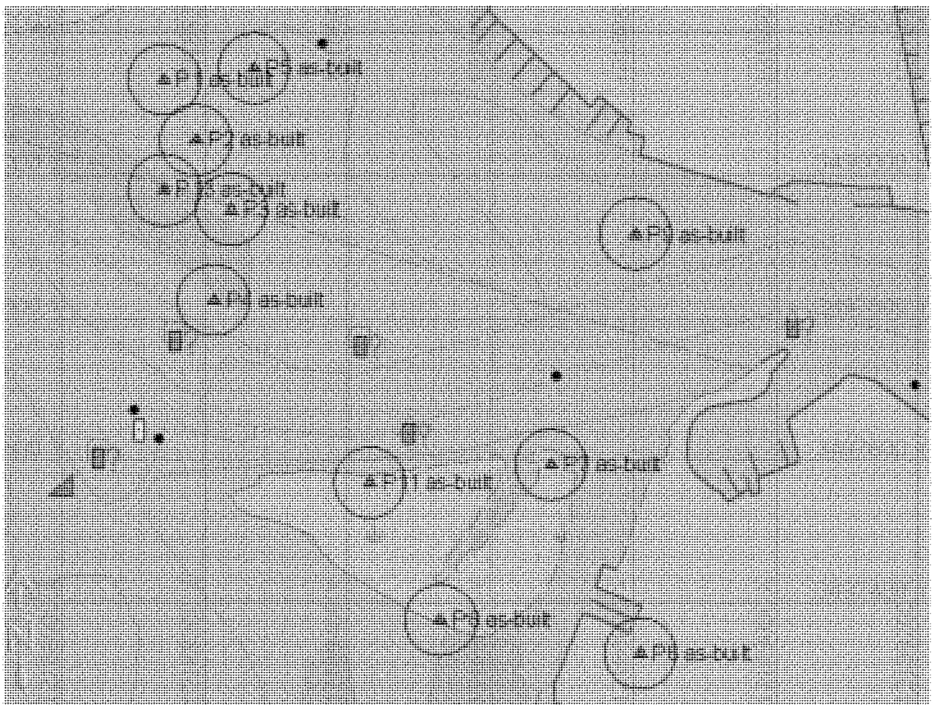


Figure 2. CORE LOCATIONS BROAD BAY

Broad Bay As-Built Core Locations
Note: NOAA S57 background chart is approximate, actual core locations plotted
Grid System: NAD83, VA South State Plane, US Survey Feet

Broad Bay

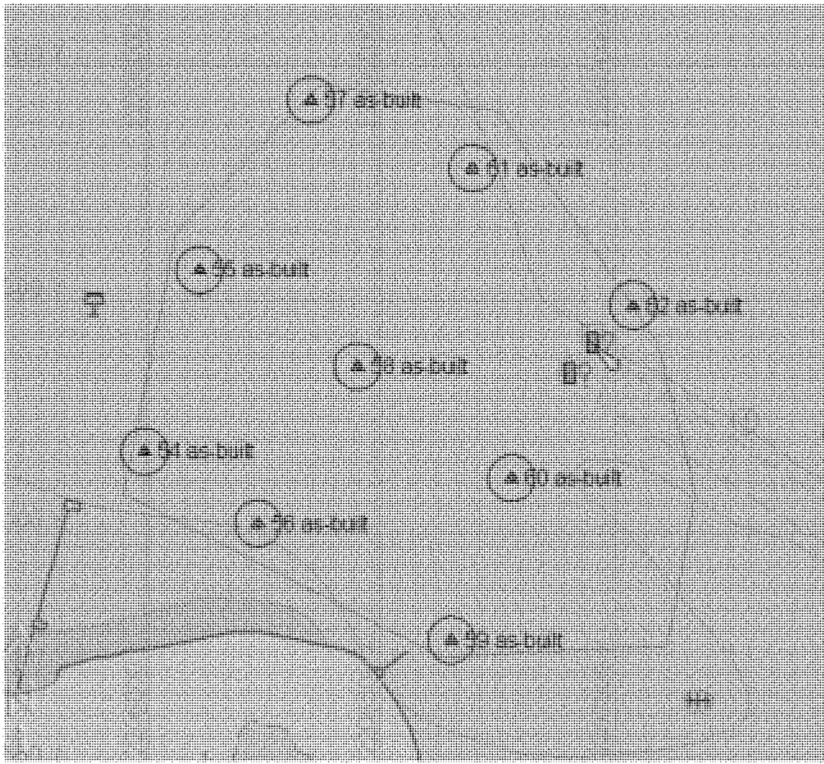


Figure 3. CORE LOCATIONS BROWN COVE

Brown Cove As-Built Core Locations
Note: NOAA S57 background chart is approximate, actual core locations plotted
Grid System: NAD83, VA South State Plane, US Survey Feet

Brown Cove

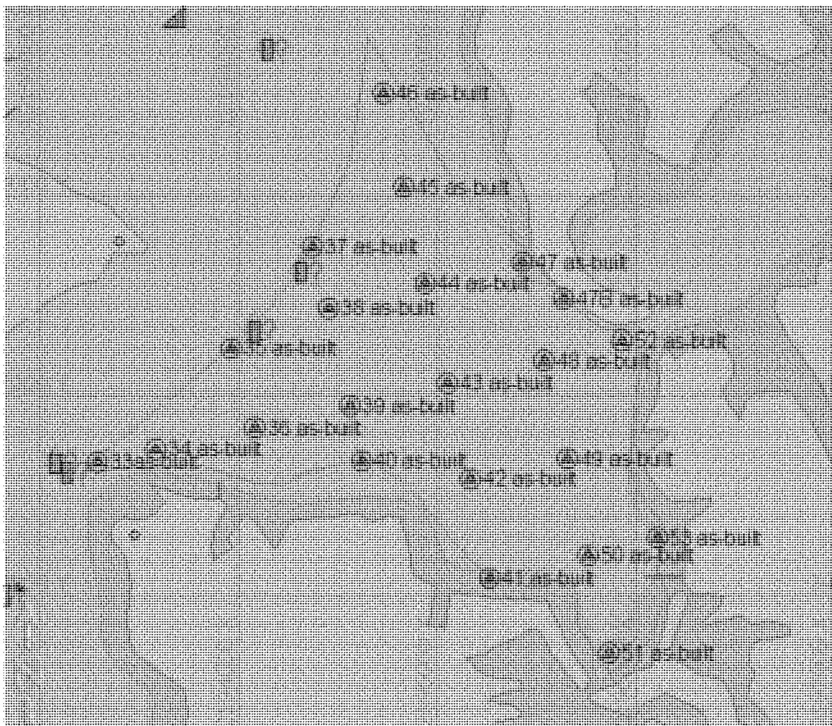


Figure 4. CORE LOCATIONS BROCK COVE

Brock Cove As-Built Core Locations
Note: NOAA S57 background chart is approximate, actual core locations plotted
Grid System: NAD83, VA South State Plane, US Survey Feet

Brock Cove

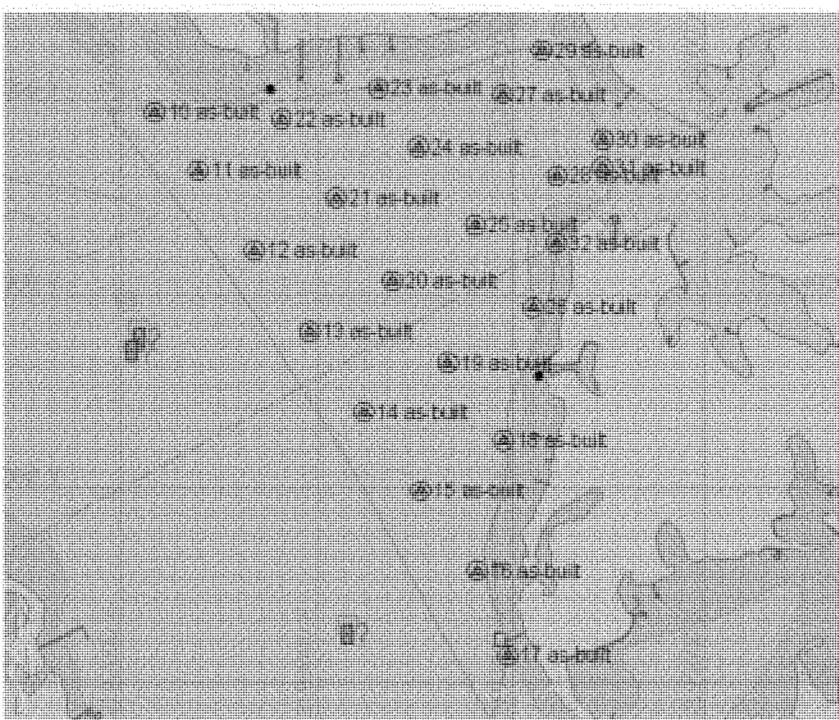
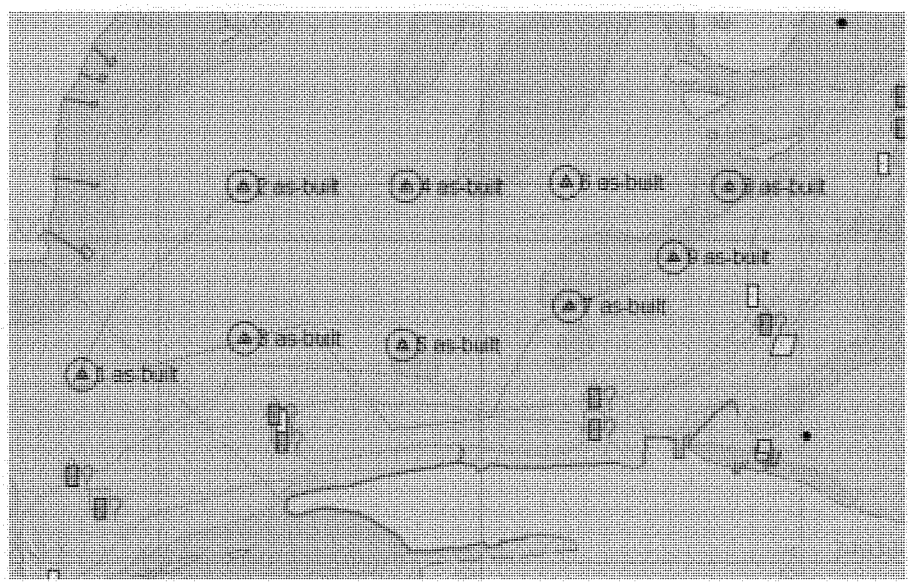


Figure 5. CORE LOCATIONS HILL POINT

Hill Point As-Built Core Locations
Note: NOAA S57 background chart is approximate, actual core locations plotted
Grid System: NAD83, VA South State Plane, US Survey Feet

Hill Point



CONCEPTUAL DESIGN ALTERNATIVES

General

Concept-level designs were developed for reef habitat, wetland creation and wetland restoration/diversification sites considered for evaluation. The SAVand bay scallop alternatives are explained in detail in the main report and are not included in this appendix with the exception that the information from the geotechnical investigations and the hydrodynamic modeling was used to identify potential sites based on bottom conditions and flow patterns.

Reef Habitat

There are nine sites identified for restoration of essential fish habitat utilizing reef balls within the Lynnhaven River. Four sites, totaling approximately 10.5 acres, were located for the construction of reef structure in the Lynnhaven mainstem. The restoration measure for these sites would involve placement of low relief reef balls that are approximately two feet in height. The five sites are in the Broad Bay/Linkhorn Bay complex and make up approximately 21 acres of potential fish reefs. Reef habitat (reef balls) designs were derived mainly from the website: reefball.org. Placement of high relief reef balls, up to 6 feet in height, was evaluated based on water depth and densities required for environmental benefits as described in the environmental appendix. An 8'x8'x12" geogrid mattress would be placed under reef ball in areas where soft bottom conditions exist. The selected plan locations are dispayed in plates 2 and 3 of the main report.

Table 4. REEF BALL PROPERTIES

Style	Width	Height	Weight	Concrete Volume	Surface Area	# Holes
Goliath	6 feet	5 feet	4,000-6,000 lbs.	1.3 yard3	230 ft2	25-40
Super Ball	6 feet	4.5 feet	4,000-6,000 lbs	1.3 yard3	190 ft2	22-34
Ultra Ball	5.5 feet	4.3 feet	3,500-4,500 lbs.	0.9 yard3	150 ft2	22-34
Bay Ball	3 feet	2 feet	375-750 lbs.	0.10 yard3	30 ft2	11-16

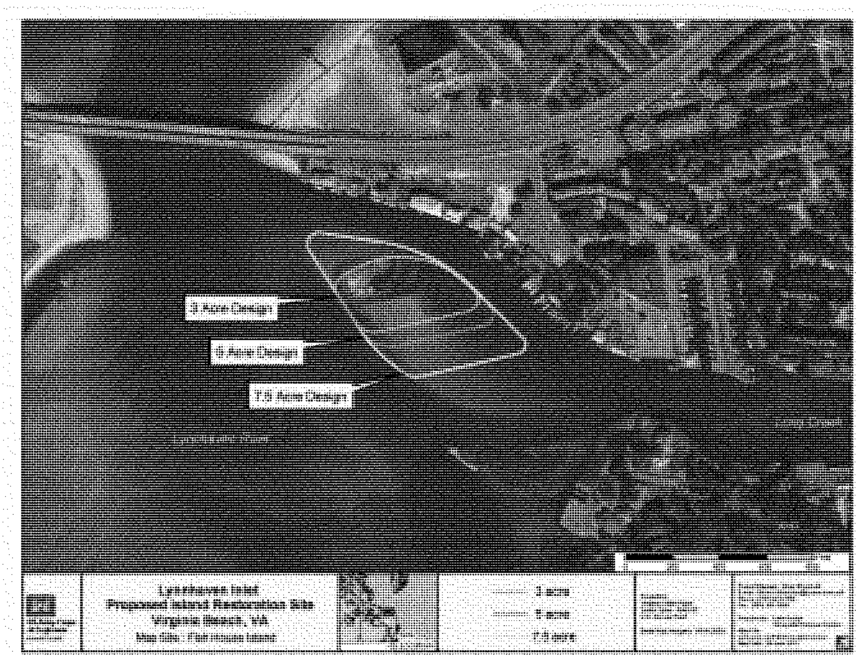
Figure 6. REEF BALL PHOTO

Wetland Creation

Three areas have been identified by the sponsor and resource agencies for wetland creation. The sites indentified are as follows: Fish House Island, Narrows to Rainey Gut and Lake Windsor. Wetland site size and shapes were largely dictated by the exiting site conditions such a bank type, depth of water, fetch and characteristics of adjacent shorelines. Proposed wetland plant elevations were determined by assessing elevations of nearby native plant areas. Coastal Engineering Design and Analysis System (CEDAS) was used to determine rocks sizes, structure dimensions and slopes.

Fish House Island (Figure 8) , located just inside the mouth of the Lynnhaven Inlet, is an example of an island within the Lynnhaven River Basin that has lost significant area and was determined to be a potential site for marsh restoration. Historical aerial photography shows that Fish House Island was approximately 10 acres in size in the 1930's, however the present area covers approximately 1.25 acres.

<u>Figure 7. FISH HOUSE ISLAND</u>



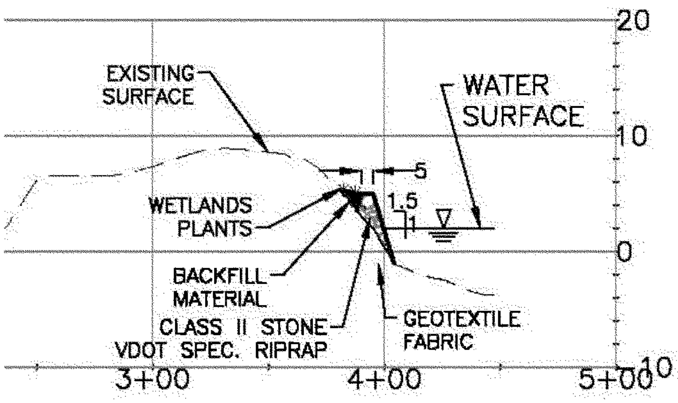
Some risk is associated with the restoration of Fish House Island. Erosion occurring on the island is due to swift currents experienced during maximum flood and ebb tides. The restoration of the island will not eliminate these currents and could increase the velocity of the currents due to a reduced cross section outside of the main channels. Even with that associated risks, this measure represents an opportunity to restore significant amounts of lost wetlands in the Lynnhaven watershed, so this site was carried forward in the study. Three different options were evaluated. These include the "small island" option that included 3 acres of restoration, the "medium island" option that would result in 5 acres of marsh and finally the "large island" option, which included 7.5 acres of restoration.

The Narrows to Rainey Gut (NR) site consists of an eroding fast-land bank ranging from 3 to 6 feet in height with an exposed berm at low tide approximately 20 feet wide. The shoreline is facing south –south west with an effective fetch of less than a mile to the south. The major design features include a trapezoidal stone riprap sill to protect wetland plants and stabilize the shoreline.

Figure 8. NARROWS TO RAINEY GUT STUDY AREA

Figure 9. NARROWS TO RAINEY GUT PROJECT SITE

Figure 10. NARROWS TO RAINEY GUT CROSS SECTION



The Lake Windsor (LW) site consists of an eroding fast-land bank ranging from 1 to 3 feet in height. The shoreline is facing south with an effective fetch of about 0.1 miles to the south. The major design features include a trapezoidal stone riprap sill to protect wetland plants and stabilize the shoreline.

Figure 11. LAKE WINDSOR STUDY AREA

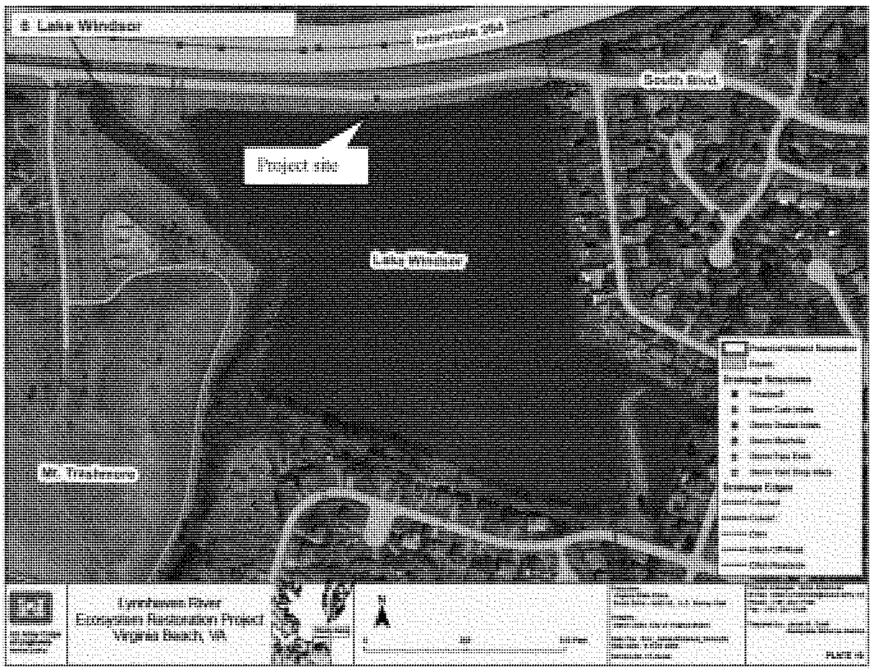


Figure 12. LAKE WINDSOR PROJECT LOCATION

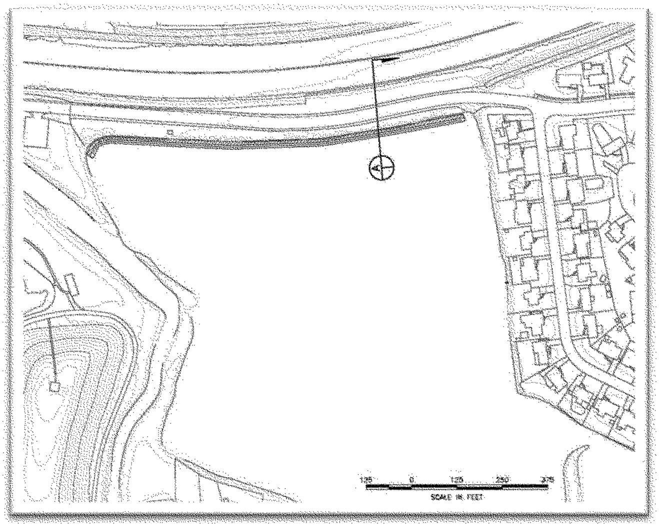
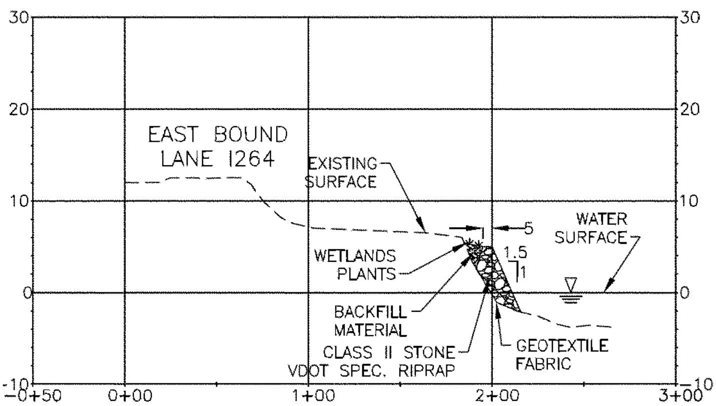


Figure 13. LAKE WINDSOR CROSS SECTION



Wetland Restoration/ Diversification Sites

Four sites within the Lynnhaven River Basin have been identified for restoration or diversification efforts in the Lynnhaven Restoration Project. Each site contains established stands for the nonnative, invasive, emergent plant, *P. australis*.

Princess Anne Site. The Princess Anne site (PA) is "half moon" shaped, with a fringe marsh, and approximately 3.82 acres in size (Figure 14). The site is located northeast of Virginia Beach Town Center, in a highly developed area of the city. The regions south and west of the site are highly urbanized, consisting of large, multistoried buildings and impervious surfaces, such as parking lots and roadways. The areas situated to the north and east of the PA site are made up of residential neighborhoods of single family housing units.

The western edge of the PA site flanks Princess Anne High School and Thalia Lynn Baptist Church. A 50 to 100-foot wide forested buffer zone separates the marsh from the large parking lots, buildings, and recreational fields of the school and church. Thurston Branch runs along the eastern edge of the site. On the opposite shore across from the PA site, a single line of trees separates Thurston Branch from Thalia Elementary School. The school property is comprised of numerous buildings, a parking lot, and maintained lawn. A drainage channel separates the PA site from another fragment of salt marsh approximately 1 acre on the site's southern edge.

Thurston Branch runs along the entire eastern margin of the PA site, so tidal inundation is not restricted to the site. There is approximately 0.3 miles of shoreline, composed of a thin band of tidal flats and native vegetation, located along the site boundary. Immediately inland of the shoreline is a narrow, wooded, island that runs most of the length of the site. The area situated between the wooded island and the upland buffer, approximately 3 acres, is dominated entirely by *Phragmites austrialis*. The marsh running along the southern edge of the project site is vegetated with native salt marsh plants.

Figure 14. THE PRINCESS ANNE WETLAND RESTORATION SITE, VIRGINIA BEACH, VIRGINIA

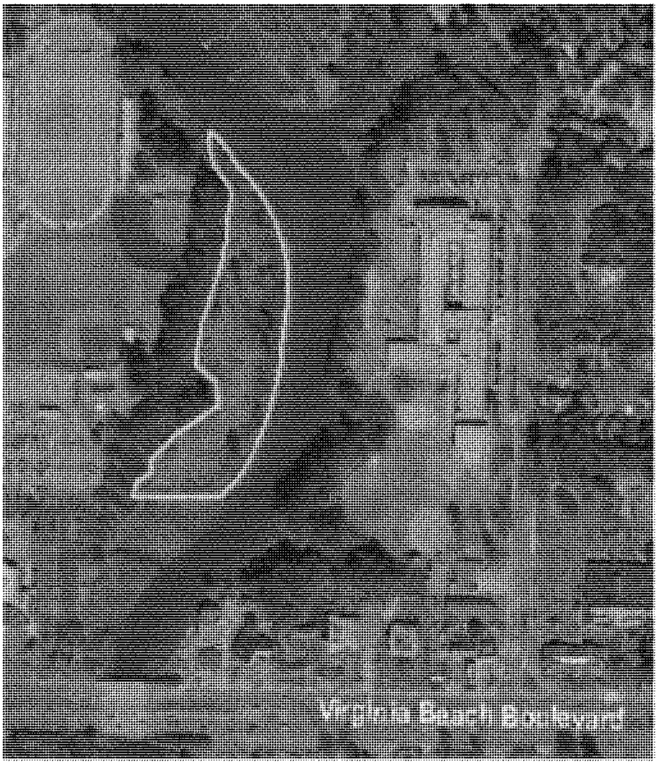
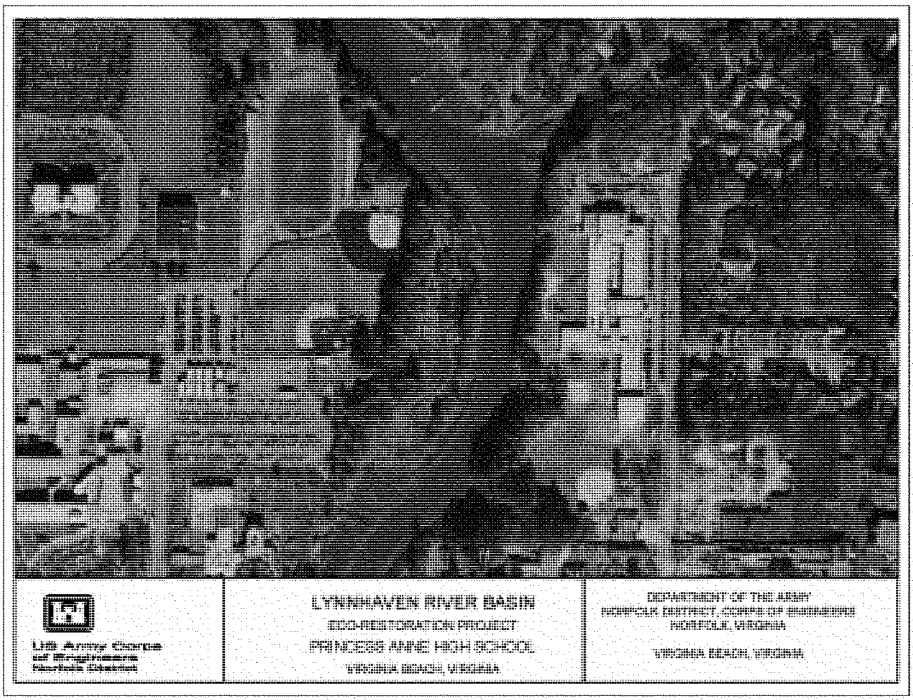


Figure 15. THE PRINCESS ANNE WETLAND RESTORATION SITE, VIRGINIA BEACH, VIRGINIA



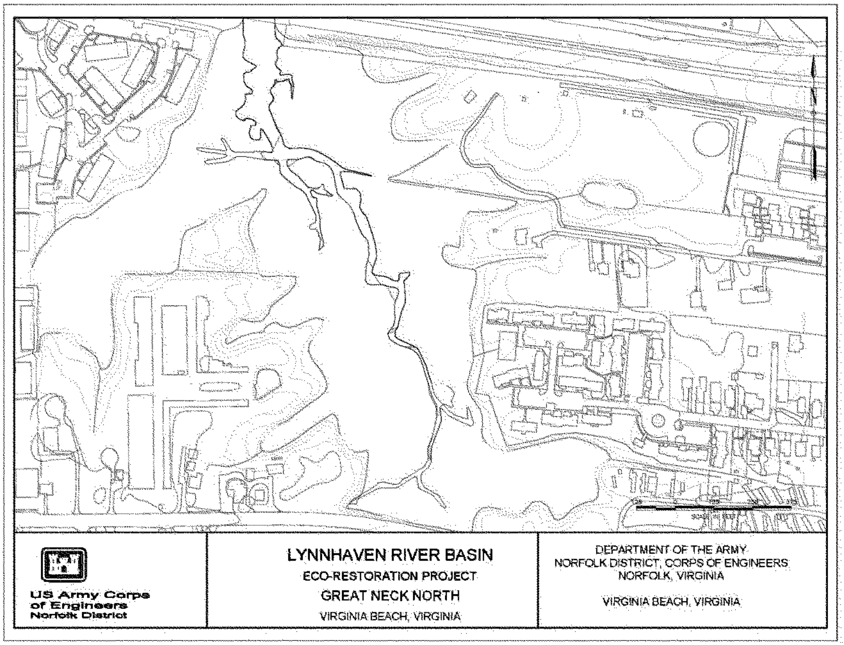
Great Neck North Site. Great Neck North (GNN) is the largest wetland site included in the Lynnhaven Restoration Project, consisting of 19.98 acres of tidal marsh (Figure 6). The GNN site is a long, narrow salt meadow running north to south. It is approximately .33 miles in length, and varies between .05 and 0.16 miles in width. The northern edge of the GNN site is defined by a bridge allowing Route 264/ Virginia Beach Expressway to cross the channel which connects the marsh to Linkhorn Bay. Tidal flushing of the site is not restricted by the bridge. The southern limit of the site is established by Virginia Beach Boulevard. A Dominion Power right-of-way defines the entire western edge of the site. The upland beyond the right-of-way is made up of a narrow, forested border, and the buildings, lawns, and paved parking lots of the two apartment complexes and the self storage business that have been constructed adjacent to the site. The eastern side of the GNN site is developed with an apartment complex, a police academy, a trailer park, and a small number of single family houses. Most of the eastern edge has a narrow buffer zone separating the marsh from the developed upland. Beyond the buffer, the upland adjacent to the site is composed of maintained lawns, structures, and impervious surfaces.

The GNN site possesses a high level of diversity, both in vegetation and habitat types. Open water habitat is provided by the central channel that runs through the site from north to south and a single secondary channel that split off the main channel. The marsh has not been extensively ditched. A few bare pannes and dead standing trees can be found throughout GNN and tidal flats are located at the northern edge of the site. Wooded island habitat can be found in the northwest corner.

A native salt marsh plant community, including *Spartina* species and marsh shrubs, is present at the site; however, the area also contains large stands of *Phragmites australis*. The northern and eastern quadrants of the GNN site are dominated by native plant species. *P. australis* fringes the main marsh and grows in large stands at drainage structures where freshwater enters the system. *P. australis* is starting to encroach on areas that are dominated by cordgrass and other native plants. The southern part of the GNN site is a mixture of native species and *P. australis*. However, larger amounts of the invasive common reed are present in this area than are found in the northern and eastern sections. The western quadrant of the site is made up almost entirely of *P. australis*, including the area west of the wooded islands that are located in the northwest corner of the site, the entire Dominion Power right-of-way, and the wetlands located to the west of the right-of-way.

Figure 16. THE GREAT NECK NORTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA

Figure 17. THE GREAT NECK NORTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA

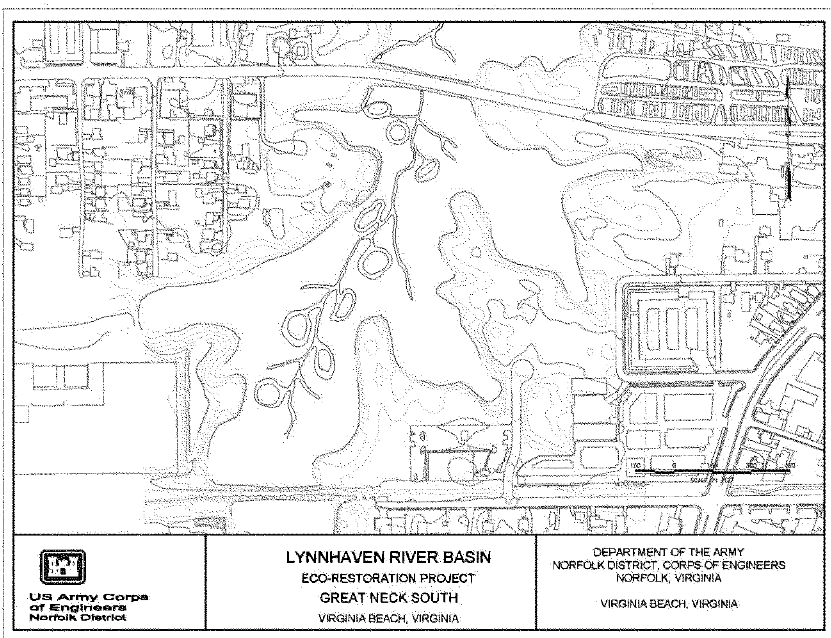


Great Neck South Site. Great Neck South (GNS) site is connected to GNN via two, small culverts that run under Virginia Beach Boulevard (Figure 7). The culverts that link the sites restrict tidal flow between the two marshes. The GNS site is a large (13.68 acres), narrow salt meadow running from north to south. The site has similar dimensions as GNN, being about 0.32 miles in length and varying between 0.05 and 0.16 miles in width. The northern edge of the site is defined by Virginia Beach Boulevard and the southern edge is marked by a railroad trestle. The Dominion Power right-of-way present at the GNN site continues along the entire western edge of the GNS site. Beyond the right-of-way, the land adjacent to the western edge contains two large commercial properties, one of which is an auto salvage yard. This area consists of large parking lots, commercial buildings, wooded uplands, and a containment pool. The eastern edge of the GNS site contains two relatively large wooded areas, one being approximately 7.5 acres in size and the other being about 5.5 acres. Three commercial properties are also located in the eastern tract, including two self storage businesses. The area consists of wooded uplands, impervious surfaces, commercial buildings, maintained lawn, and about 1.5 acres of bare earth.

The diversity in habitat type and plant species at the GNS site is low. One central channel runs the length of the marsh from north to south. The marsh is not extensively ditched, but a few small drainage channels empty into the main central stream. Wetland shrubs grow along the central channel and a few bare pannes are located in the site. However, the majority of the site is vegetated with extremely dense stands of *P. australis*.

Figure 18. THE GREAT NECK SOUTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA

Figure 19. THE GREAT NECK SOUTH WETLANDS SITE, VIRGINIA BEACH, VIRGINIA



Mill Dam Creek Site. The wetland site with the smallest area is Mill Dam Creek (MDC) site, approximately 0.9 areas in size (Figure 8). The site is a long, narrow marsh running from north to south. The northern edge of the site is delineated by Mill Dam Road. The southern edge of the site consists of wooded uplands. Both the eastern and western edges of the site abut residential property. The area surrounding the site consists of wooded upland, manicured lawns, single family houses, and roadways. Culverts that run under Mill Dam Road connect the site to Mill Dam Creek, which eventually empties into Broad Bay.

Tidal flow into the MDC site is severely restricted by the culverts. One central channel runs through the site and no ditching is evident. Other than shrubs that grow along the central channel and a few dead standing trees, the marsh is composed entirely of extremely dense *P. australis* stands.

Figure 20. THE MILL DAM CREEK WETLANDS SITE, VIRGINIA BEACH, VIRGINIA

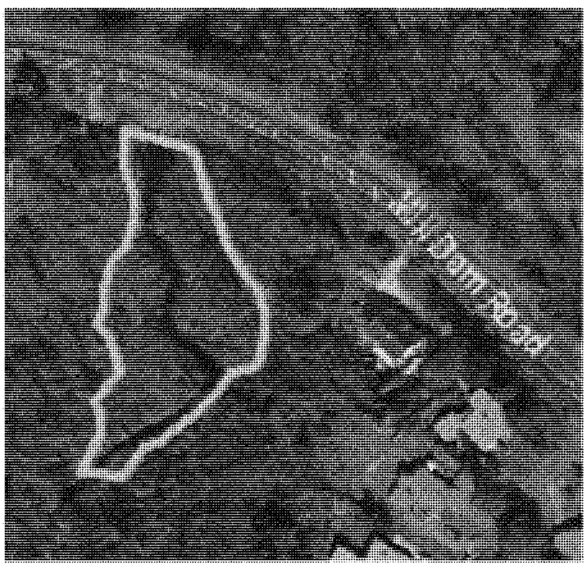
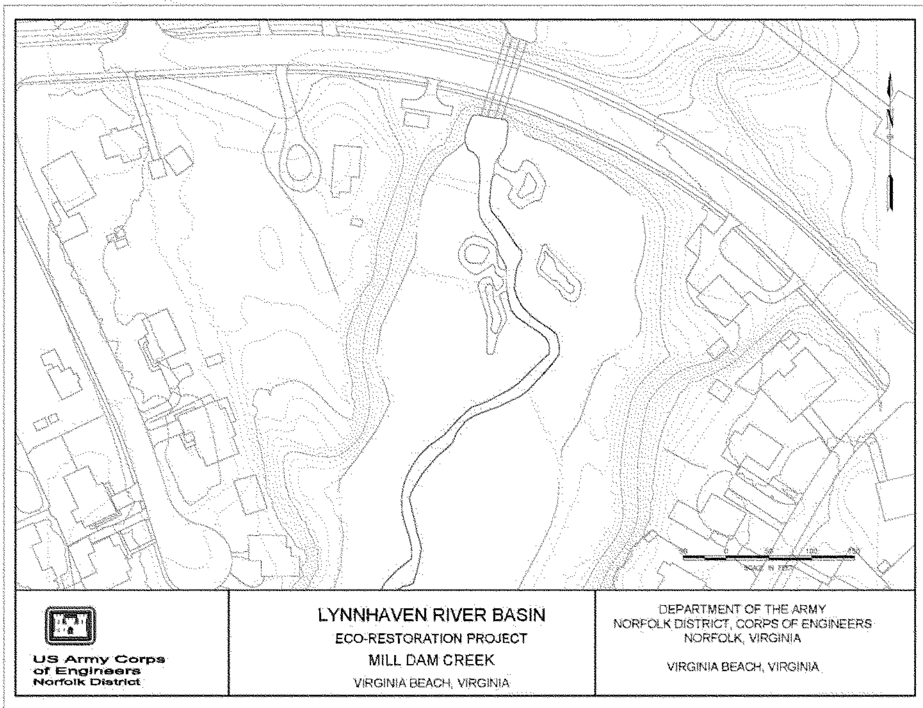


Figure 21. THE MILL DAM CREEK WETLANDS SITE, VIRGINIA BEACH, VIRGINIA



CONSTRUCTION PROCEDURES

Excavation, material hauling, and disposal of the excavated material is dependent on the contractor's means and methods and are thus unknown at this time. Reasonable options are listed for excavation, hauling of materials off-site, and the eventual disposal site for material and debris. Excavation options include:

- Digging with track-mounted hydraulic excavators.
- Scrapping with bulldozers.
- Digging by crane with dragline or clamshell bucket.
- Some combination of the above.

Hauling options include:

- Trucking material directly from the excavation site to the eventual disposal site, with road-capable vehicles that might include any combination of 10-cy dump trucks, 10-cy dump trucks pulling an 8-cy dump trailer, or 20-cy side dump trucks.

Disposal options include:

- Local landfills such as Portsmouth, SPSA (Suffolk), Holland Enterprises (Suffolk), and Bethel (Hampton).

Construction Sequence

The anticipated sequence of construction steps to be taken by the contractor is as follows:

1. Submit an Erosion Control Plan, based on contractor's means and methods at least 30 days before commencing work at the site.
2. Obtain Land Disturbing Permit from the City of Virginia Beach before commencing work.
3. Verify location and elevations of existing survey control markers. Perform construction staking survey to establish final lines and grades. Prior to start of earthwork, the Contractor shall verify all project vertical and horizontal datums.
4. The Contractor shall verify elevations of existing adjacent marshes and notify the Contracting Officer of any discrepancies in proposed planting elevations.
5. Install erosion and sediment control structures including temporary stone construction entrance, construction road stabilization, safety fence, silt fences, and tree preservation and protection.
6. Mow and spray herbicides within limits of Common Reed Zone to prevent common reed (phragmites) recontamination of exposed wetland excavation.
7. Excavate shoreline to lines and grades shown on the plans.
8. Stockpile sufficient excavated material meeting topsoil requirements to use as backfill in those final grade areas not meeting topsoil requirements and thereby requiring over-excavation and topsoil backfill.
9. Place filter-cloth and riprap to the line and grades as shown on the plans.
10. Plant new wetland vegetation as specified and shown on drawings and install goose exclusion fencing.

11. Upon work completion and when the site is stabilized to the satisfaction of the Contracting Officer, remove the temporary erosion and sediment control devices and stabilize those areas disturbed by the processes.
12. Restore any existing areas impacted by construction activities by bringing to grade and planting elevation.

Erosion Control Requirements

Erosion and sediment control design measures in accordance with provisions in the Virginia Erosion and Sediment Control Handbook (1992) are appropriate for the construction of the wetland sites and will be strictly followed. Erosion and sediment control measures include:

- Safety fence per Standard and Specification 3.01
- Construction Entrance per Standard and Specification 3.02
- Construction Road Stabilization per Standard and Specification 3.03
- Silt fence per Standard and Specification 3.05
- Permanent seeding per Standard and Specification 3.32
- Tree preservation and protection per Standard and Specification 3.38
- Dust control per Standard and Specification 3.39.

OPERATIONS AND MAINTENANCE

Operations and maintenance requirements for the wetland sites include a yearly inspection of the areas to ensure native plant growth and no encroachment of evasive plant species. Upon inspection it would be determined if additional sprig plants or the application of herbicides is necessary to restore the required wetland function. An assessment of the rock structures for displacement from wave action and/or settlement due to long term consolidation of the subgrade should also be included in the inspection. The non-Federal sponsor is responsible for all operations and maintenance features of the project.

RELOCATIONS

No relocations of infrastructure or public services, such as water service and/or electrical service, are known to be located in the areas needed for construction of the Tentatively Selected Plan. However, as with the case with all construction activities, all utility companies shall be contacted before construction is initiated.

COST ESTIMATES

Cost Estimate for Selected Plan

Introduction: The Lynnhaven River Basin is located in the city of Virginia Beach and discharges into the Chesapeake Bay. The river basin covers 64 square miles and supports recreational boating and fishing, crabbing, ecotourism, and general environmental observation. The project objective is to develop a solution that reasonably maximizes environmental restoration benefits compared to costs and is consistent with Federal and city objectives.

1. Project Description

   a. General: The proposed Lynnhaven Ecosystem Restoration Project is designed to improve habitat and biodiversity in the Lynnhaven River Basin, a tributary of the Chesapeake Bay. These restoration activities involve wetland restoration, hard reef habitat reef structures, submerged aquatic vegetation (SAV) establishment, and scallop restoration. Also see main report for background.

   b. Purpose: This feasibility study includes a plan which will improve water quality, restore and protect the environment, and provide other ecosystem benefits.

   c. Design Features: There are four main design-construction features. One is the improvement of wetland/march habitat through removal of non-native plants and restoration of restore native marsh grasses and natural drainage. The second is to restore underwater vegetation similar to what was once prevalent in this area. The third measure is to reintroduce bay scallops in the Lynnhaven River System. The fourth measure is to improve fish habitat with reef balls of various sizes at different locations throughout the river system. The design, for practical purposes, is developed only to a 30% conceptual design stage as this is a feasibility level effort. Detailed plans and specifications are not yet developed, even to a level to that has incorporated value engineering considerations.

2. Basis of Estimate

   a. Basis of Design: Lynnhaven River Basin Environmental Restoration Study, Virginia Beach, Virginia plans.

   b. Basis of quantities: The estimate development is from quotes, calculations, and unit prices. Unit prices are primarily developed with labor, equipment, and material components. Backup for these unit prices include production rates and crew output calculations shown on other sheets. The quantities are from plan takeoffs where possible. Designers provided information and quantities based on their objectives for SAV, Bay Scallops, and Reef Balls. Very little of this project can be considered typical concrete and rebar construction. Nearly all elements are unique or atypical, such as submerged aquatic vegetation (SAV) seeding, scallop seeding, and reef creation. The cost team has developed detailed estimates for the reef placement and other elements to the level of detail in the design, or what could be reasonably assumed by the estimator. Some of the minor elements (comprising less than 1% of the total cost) are priced based on historical data and assumed production rates as the project lacks specification detail at this feasibility stage.

c. Quotes: Reef Ball costs are from Reef Innovations, Inc, Sarasota, Florida; Larry Beggs (914-330-0501). Todd Barber of the Reef Foundation (941-484-7482) also provided cost information on reef balls. Sea Search of Virginia who provided the previous quote is no longer in business. The number of other regular suppliers of reef balls has decreased over the last 15 years. Marine mattresses serve as the foundation for reef balls in the softer, less stable bottom material in the Lynnhaven area. Quote information is from Jeff Fiske: Coastal & Waterway Industry Manager, Tensar International Corporation (770) 344-2123. Alan Dinges of Maccaferri, Inc; Williamsport, MD also provided information (301)-223-6910.

d. Estimate Development: The estimate employed the Mii estimating software for all work items. The project is treated as a total project in the cost estimate, with separate mobilizations included for wetland sites and reef ball installation. The wetland estimate is primarily earthwork and planting of new grasses/plants. These costs are from similar projects and the 2012 Corps of Engineers Cost Book. SAV and Bay Scallop pricing is from experienced experts in these fields.

e. Reef ball estimate: This estimate includes the material cost and the cost to deliver and place the reef balls. The project plan includes four different reef ball sizes. The bay ball is only about 3' in diameter. The goliath, super, and ultra balls are approximately 6' in diameter. The effort and time to install the large reef ball is similar for all large sizes, which vary only incrementally. Further refinement of the design will be needed to compensate for soft bottom reef placement. Stone filled marine mattresses alleviate the soft bottom conditions.

f. Reef ball placement: Five separate operations estimated by assemblies give the cost of the transportation and placement of the balls. The assumption was that a casting yard located in the Norfolk area would manufacture the reef balls. A small crane loads the balls onto a truck, which transports them to a storage area next to the water in the Lynnhaven area. A small crane unloads the truck and stockpiles the balls. After stockpiling, a small crane then loads a barge with the balls and a tug moves the barge to correct placement location. A second barge with a crane places the balls in the river. Movement of the balls requires a determination of cycle times and creation of crews in the assembly. Assumptions include the use of small 2 to 5 man crews for water based operations, shallow draft barges, and a two-barge system for transport of the balls where loading of one barge occurs at the same time as placement from the second barge. Divers provide final location help and verification for placing the balls. Water-based labor costs and workmen's compensation rates are from the Corps of Engineers Dredge Estimating Program (CEDEP) and Davis-Bacon wage rates. Wetlands Restoration labor costs are from Davis-Bacon rates. Equipment rates were from the 2011 Corps of Engineers Equipment database.

g. Site Access: Site access depends on the specific type of work. Fish habitat/reef balls, SAV's, and Bay Scallops construction will be by barge or boat. The area should be accessible throughout the year. Weekend work is not as practical because of the boat traffic in the area, especially in the summer. Earthwork and marsh planting access will be by the closest most reasonable point from land.

h. Borrow Area: There is no borrow area within the project limits of this study. Borrow material comes from offsite.

i. Mobilization: Mobilization of excavators and dozers will be by truck. Tugs will move barges, while other floating equipment may be self-propelled. Reef Ball construction will have multiple mobilizations because of the multi-year contract setup. The cost of mobilization for SAV and Scallop establishment will be small.

j. Overtime: The cost estimate includes overtime for labor for wetlands restoration and installation of the reef ball features. The remainder of the project for SAV seeding and scallop introduction did not warrant overtime production.

k. Profit has been calculated from the weighted guidelines method. The project is treated as a total project in the cost estimate, with separate mobilizations included for wetland sites and reef ball installation. The only contract that will require substantial field overhead is Base Contract 1 for wetland restoration and fish reef habitat. In this case we have included itemized FOOH for the three year duration of reef ball installation, monitoring, and adaptive management. SAV and Scallop work is mostly conducted from small craft skiff- type boats, and there are several boat ramps in the Lynnhaven to allow direct access to project sites for seeding of both project elements and monitoring.

l. Bond: Bond is now determined from the MII program.

m. TPCS (Total Project Cost Summary) The TPCS summarizes the main features of work. The features include Wetland Restoration, Reef Habitat Construction, SAV construction, and Scallop construction. These are all in CWWBS Category 06 Fish & Wildlife. As seen in the construction schedule there are three main contracts and multiple phases within each contract. Reef ball phasing allows a smaller contractor to bid on the job. Some contractors may not have enough resources to build all the reef balls in one contract in a limited time. Phasing and pilot construction of SAV's and Scallops allows monitoring and adaptive management to increase the chances for project success. The Mii estimate is broken out into separate contracts and phasing to match the schedule. The estimator transferred these work items into the TPCS. These individual work segments have separate escalation factors applied to reach the fully funded level in the TPCS. A summary of these individual work items is on the first/title TPCS page. The project cost basis is 01 October 2012. The Program Year is 2014. Work begins in FY 2017 and continues to FY 2023. See the project schedule for detailed items. The TPCS (Total Project Cost Summary) shows escalated construction costs to midpoints of construction for the various work items.

n. Other considerations: It is anticipated that the number of fish reef structures in this project will be sufficient for a supplier to develop a local production yard to supply the reef structures, which are relatively simple to construct. A local supply chain would tend to lower budget prices obtained from outside suppliers. As the concrete reef restoration industry grows and expands, it is likely the forecast prices will drop.

3. Construction Schedule: A feasibility level construction schedule was provided to the cost team that covers a six year period of construction and adaptive management. The schedule included projections from estimating for Wetlands Restoration and Reef Ball construction and from the "environmental" team for SAV and Scallop construction. Duration for reef ball activities is from the estimate. Adaptive management is a concept for ecosystem restoration that recognizes the limitations and external factors that influence successful restoration. Not trial and error, but a deliberate process that builds on successful efforts and lessons learned to move towards project restoration goals.

4. Acquisition Strategy There will be more than one contract for this work, because the individual projects are so different from each other. This is true especially for the Bay Scallop work, which can't begin until establishment of the SAV's (Submerged Aquatic Vegetation) in the Lynnhaven River. The provided acquisition strategy is to use three

contracts to accomplish the work using full and open competition. The acquisition plan and schedule help to mitigate project risk by providing open competition and option items that can be flexible and based on field monitoring results. Risk is also mitigated by ongoing actions of the local NGO that has already placed reef balls and similar shaped concrete structures in the Lynnhaven waterway, and they have been performing well. These actions should give the PDT added confidence as these installations are monitored for activity. The group concurred on a strategy that consists of three Firm Fixed Price contracts using full and open competition as follows:

a. Contract 1 (FFP- full and open competition): SOW= All phases of the Wetland Restoration/Diversification and Reef Habitat measures. Base contract will be awarded in first year identified for construction (2017) with two options for Phase 2 (2018) and Phase 3 (2019).

b. Contract 2 (FFP- full and open competition): SOW= SAV initial construction (3 phases). Base contract will be awarded in first year identified for construction (2017) with two options for Phase 2 (2018) and Phase 3 (2019).

c. Contract 3 (FFP- full and open competition): SOW= SAV large-scale construction (2 phases) and scallop reintroduction (3 phases). This contract would consist of a base plus three options. The base contract will be awarded in the fourth year identified for construction (2020) for the first phase of the SAV large scale construction. Option 1 will be awarded in 2021 and will consist of the 2nd large-scale phase of SAV construction and first phase of scallop reintroduction. Option 2 will be awarded in 2022 for the second phase of scallop reintroduction. Option 3 will be awarded in 2023 for the final large-scale scallop reintroduction.

5. Non-construction features:
   a. The basis for Planning Engineering and Design (E&D – Feature 30) costs are discussions with the project manager and established rates used on other jobs.
   b. The basis for Construction Management and Design (E&D – Feature 30) costs are discussions with the project manager, in-house construction personnel, and established rates used on other jobs.
   c. The cost for Lands & Damages (Feature 01) is from detailed reports submitted by Real Estate

6. Other Project Mark-ups

   a. Escalation: The project cost basis is 01 October 2012. The Program Year is 2014. Work begins in FY 2017 and continues to FY 2023. See the project schedule for detailed items. The TPCS (Total Project Cost Summary) shows escalated construction costs to midpoints of construction for the various work items. The TPCS uses the latest CWCCIS (Civil Works Construction Cost Index System) publication (March 2013) for cost growth calculations.

b. Contingency and Risk: From a risk standpoint, the project has limited life and safety issues. With full and open competition planned, the risk associated with limited competition and small business concerns are reduced. In addition the adaptive management process allows the team to control scope and direct efforts towards site specific actions. Adaptive management and associated monitoring is done in the option years associated with each of the three base contracts. Options can be tailored and exercised based on observed needs in the field. An abbreviated Risk Analysis has been accomplished and reflects a relatively low risk project from the contractor's perspective, with high risk for SAV and Scallops success. Turning around declining SAV coverage, reintroducing scallops where their numbers have been eliminated, and developing active reef habitat in a highly active waterway are all challenging aspects of the project; however, the adaptive management approach is designed to maximize potential for success. In this project the success of the scallops is highly dependent on the successful development of SAV beds. Risk is high for these components of the project due, almost entirely, to recognized external risks. The report is clear that there are no guarantees of total project success. The team's adaptive management plan includes several risk mitigation strategies if certain external risk are manifest; SAV fencing, signage, floating barriers, alternative siting, and re-seeding. The project contingencies are included for the items in the TPCS separately and reflective of the degree of risk Associated risks could cause potential scope change; however, the District intent is to design/cost manage to remain within the funds made available. The District believes that scope and quantities could be adjusted, accompanied by competitive acquisition strategies, and bid schedule construct to still meet project intent.

**** TOTAL PROJECT COST SUMMARY ****

Printed:7/26/2013
Page 1 of 8

PROJECT: Lynnhaven River Basin Ecosystem Restoration
PROJECT NO: P2 121785
LOCATION: Virginia Beach, Virginia

DISTRICT: NAO-Norfolk District COE, NAD PREPARED: 7/25/2013
POC: CHIEF, COST ENGINEER Gary Szymanski

This Estimate reflects the scope and schedule in report; Lynnhaven River Feasibility Report

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			6/29/2013	Program Year (Budget EC):			2014					
		Effective Price Level:			10/1/2012	Effective Price Level Date:			1 OCT 13	Spent Thru: 1-Oct-12				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*
06	FISH & WILDLIFE FACILITIES													
	-WETLANDS RESTORATION	$822	$148	18.0%	$970	2.1%	$839	$151	$990	$0		$898	$162	$1,059
	-ESSENTIAL FISH HABITAT	$20,214	$3,598	17.8%	$23,813	2.1%	$20,630	$3,672	$24,303	$0		$22,651	$4,032	$26,683
	-SUBMERGED AQUATIC VEGETATION	$2,763	$768	27.8%	$3,531	2.1%	$2,820	$784	$3,604	$0		$3,224	$896	$4,120
	-BAY SCALLOPS	$439	$146	33.2%	$585	2.1%	$448	$149	$597	$0		$534	$177	$711
	CONSTRUCTION ESTIMATE TOTALS:	$24,238	$4,660		$28,898	2.1%	$24,737	$4,756	$29,493	$0		$27,307	$5,267	$32,574
01	LANDS AND DAMAGES	$699	$26	3.8%	$725	2.1%	$713	$27	$740	$0		$758	$28	$787
30	PLANNING, ENGINEERING & DESIGN	$2,536	$127	5.0%	$2,663	1.8%	$2,580	$129	$2,709	$0		$2,981	$149	$3,130
31	CONSTRUCTION MANAGEMENT	$1,937	$190	9.8%	$2,127	1.9%	$1,974	$193	$2,167	$0		$2,180	$214	$2,394
	PROJECT COST TOTALS:	$29,410	$5,003	17.0%	$34,413		$30,005	$5,105	$35,110	$0		$33,226	$5,658	$38,884

CHIEF, COST ENGINEERING

PROJECT MANAGER

CHIEF, REAL ESTATE

CHIEF, PLANNING and POLICY

CHIEF, WATER RESOURCES DIVISION

CHIEF, ENGINEERING

CHIEF, CONSTRUCTION

CHIEF, ENGINEERING and CONSTRUCTION

CHIEF, PPMD

ESTIMATED FEDERAL COST:	65%	$25,275
ESTIMATED NON-FEDERAL COST:	35%	$13,609
ESTIMATED TOTAL PROJECT COST:		$38,884

Filename: TPCS-Full Lynn R Alt 'D' Current 07-25-2013rev (3).xlsx
TPCS

Lynnhaven R Ecosystem Restoration-Alt 'D" 07-24-2013

The Lynnhaven River Basin Environmental Restoration Study focuses on the Lynnhaven River Basin with an approximate area of 64 sq miles. The primary problems which this project solves are environmental restoration and protection and other water-related issues. The scope of the study includes all existing and reasonably foreseeable future conditions that may affect the ecosystem within the Lynnhaven River Basin and its three main branches; the Eastern Branch, the Western Branch, and the Broad Bay/Linkhorn Bay complex. The proposed study will assess both potential actions and the scale of those actions needed to alter the current ecologically stable state of the river system. To shift the Lynnhaven River back to a prior, more productive ecologically stable state will require a large scale effort such as is included within the proposed study. Federal share is 65% and the non-Federal share is 35%.

Estimated by	EC-EE
Designed by	Norfolk District
Prepared by	mkh
Preparation Date	6/28/2013
Effective Date of Pricing	10/1/2012
Estimated Construction Time	Days

Designed by
Norfolk District
Estimated by
EC-EE
Prepared by
mkh

Design Document	
Document Date	7/27/2012
District	Norfolk District
Contact	
Budget Year	2014
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost
UserCost1

Timeline/Currency

Preparation Date	6/28/2013
Escalation Date	10/1/2012
Eff. Pricing Date	10/1/2012
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB12EB-b: MII English Cost Book 2012-b

Labor Lyn-2012: Local Labor Library - Lynnhaven, Va Beach 2012

the website for current Davis Bacon & Service Labor Rates. Fringes paid to the laborers are taxable. In a non-union job the whole fringes are taxable. In a union job, the vacation |

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP11R02: MII Equipment 2011 Region 02-Local2

02 MIDEAST

Sales Tax	5.00
Working Hours per Year	1,450
Labor Adjustment Factor	1.01
Cost of Money	1.75
Cost of Money Discount	25.00
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.096
Gas	3.620
Diesel Off-Road	3.360
Diesel On-Road	3.900

Shipping Rates

Over 0 CWT	9.67
Over 240 CWT	8.90
Over 300 CWT	8.01
Over 400 CWT	7.19
Over 500 CWT	4.67
Over 700 CWT	4.67
Over 800 CWT	7.09

Date	Author	Note
6/4/2012	mh	Adaptive Management Costs and Monitoring: Annual monitoring will be conducted for each of the measures to ensure that project objects are being fulfilled. Adaptive management (AM) costs are included in the construction costs for each of the alternatives. The AM costs for each of the measures are estimated at 10 percent of total project costs based on the following:a. Wetland sites- the annual application of herbicides to control the growth and spread of phragmites and the annual replacement of native plantings. Physical alterations may be necessary also.b. Fish reefs-up to 10 percent of construction costs, for seeding the reefs with oyster larvae.c. SAV AM-up to 10% to reseed areas that did not establish themselves.d. Scallops- up to 10 percent, in order to restock scallops in conjunction with the predation prevention measures.
7/22/2013	mh	Quote1- Reef Ball costs are from Reef Innovations, Inc, Sarasota, Florida; Larry Beggs (914-330-0501). Todd Barber of the Reef Foundation (941-484-7482) also provided cost information on reef balls. Sea Search of Virginia who provided the previous quote is no longer in business. The number of other regular suppliers of reef balls has decreased over the last 15 years.
7/22/2013	mh	Marine Mattress quotefrom: Jeff Fiske: Coastal & Waterway Industry Manager, Tensar International Corporation (770) 344-2123. Additional information is from Norfolk District coastal engineer.

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	MiscOwner	ProjectCost	C/O
Project Cost Summary Report			**24,238,220**	**0**	**0**	**0**	**0**	**24,238,220**	
			24,238,219.70					*24,238,219.70*	
Construction Cost	**1.00**	**EA**	**24,238,220**	**0**	**0**	**0**	**0**	**24,238,220**	
			24,238,219.70					*24,238,219.70*	
06 Fish and Wildlife Facilities	**1.00**	**EA**	**24,238,220**	**0**	**0**	**0**	**0**	**24,238,220**	
			24,238,219.70					*24,238,219.70*	
0603 Wildlife Facilities & Sanctuary	**1.00**	**EA**	**24,238,220**	**0**	**0**	**0**	**0**	**24,238,220**	
			24,238,219.70					*24,238,219.70*	
060373 Habitat and Feeding Facilities	**1.00**	**EA**	**24,238,220**	**0**	**0**	**0**	**0**	**24,238,220**	
			21,036,483.36					*21,036,483.36*	
Contract 1-Wetland Restoration & Reef Habitat Constriction	**1.00**	**EA**	**21,036,483**	**0**	**0**	**0**	**0**	**21,036,483**	
			121,441.44					*121,441.44*	
Contract 2 - SAV Initial Construction	**1.00**	**EA**	**121,441**	**0**	**0**	**0**	**0**	**121,441**	
			3,080,294.90					*3,080,294.90*	
Contract 3 - SAV Construction & Bay Scallops	**1.00**	**EA**	**3,080,295**	**0**	**0**	**0**	**0**	**3,080,295**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
Contract Cost Summary Report				**18,729,950**	**102,683**	**18,832,632**	**5,405,587**	**24,238,220**	
Construction Cost	**1.00**	**EA**		*18,729,949.86* **18,729,950**	**102,683**	*18,832,632.49* **18,832,632**	**5,405,587**	*24,238,219.70* **24,238,220**	
06 Fish and Wildlife Facilities	**1.00**	**EA**		*18,729,949.86* **18,729,950**	**102,683**	*18,832,632.49* **18,832,632**	**5,405,587**	*24,238,219.70* **24,238,220**	
0603 Wildlife Facilities & Sanctuary	**1.00**	**EA**		*18,729,949.86* **18,729,950**	**102,683**	*18,832,632.49* **18,832,632**	**5,405,587**	*24,238,219.70* **24,238,220**	
060373 Habitat and Feeding Facilities	**1.00**	**EA**		*18,729,949.86* **18,729,950**	**102,683**	*18,832,632.49* **18,832,632**	**5,405,587**	*24,238,219.70* **24,238,220**	
Contract 1-Wetland Restoration & Reef Habitat Constriction	**1.00**	**EA**		*16,327,919.11* **16,327,919**	**102,683**	*16,430,601.74* **16,430,602**	**4,605,882**	*21,036,483.36* **21,036,483**	
Wetland Restoration w/Phragmites Removal	**1.00**	**EA**		*593,278.65* **593,279**	**92,004**	*685,282.21* **685,282**	**136,722**	*822,004.36* **822,004**	
Essential Fish Habitat (EFH)	**1.00**	**EA**		*15,734,640.45* **15,734,640**	**10,679**	*15,745,319.53* **15,745,320**	**4,469,159**	*20,214,479.00* **20,214,479**	
Contract 2 - SAV Initial Construction	**1.00**	**EA**		*90,285.00* **90,285**	**0**	*90,285.00* **90,285**	**31,156**	*121,441.44* **121,441**	
SAV Pilot Construction-Phase 1	**1.00**	**EA**		*30,095.00* **30,095**	**0**	*30,095.00* **30,095**	**10,385**	*40,480.48* **40,480**	
SAV Pilot Construction-Phase 2	**1.00**	**EA**		*30,095.00* **30,095**	**0**	*30,095.00* **30,095**	**10,385**	*40,480.48* **40,480**	
SAV Pilot Construction-Phase 3	**1.00**	**EA**		*30,095.00* **30,095**	**0**	*30,095.00* **30,095**	**10,385**	*40,480.48* **40,480**	
Contract 3 - SAV Construction & Bay Scallops	**1.00**	**EA**		*2,311,745.75* **2,311,746**	**0**	*2,311,745.75* **2,311,746**	**768,549**	*3,080,294.90* **3,080,295**	
SAV's - Submerged Aquatic Vegetation	**287.98**	**ACR**		*6,883.60* **1,982,340**	**0**	*6,883.60* **1,982,340**	**659,037**	*9,172.08* **2,641,377**	
Bay Scallop	**1.00**	**EA**	**Prime3 - Scallops and SAV Construction**	*329,405.75* **329,406**	**0**	*329,405.75* **329,406**	**109,512**	*438,918.01* **438,918**	

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Project Direct Costs Report			**4,705,322**	**1,429,697**	**10,255,225**	**18,729,950**	**18,729,950**
			4,705,322.36	*1,429,696.86*	*10,255,224.89*	*18,729,949.86*	*18,729,949.86*
Construction Cost	**1.00**	**EA**	**4,705,322**	**1,429,697**	**10,255,225**	**18,729,950**	**18,729,950**
			4,705,322.36	*1,429,696.86*	*10,255,224.89*	*18,729,949.86*	*18,729,949.86*
06 Fish and Wildlife Facilities	**1.00**	**EA**	**4,705,322**	**1,429,697**	**10,255,225**	**18,729,950**	**18,729,950**
			4,705,322.36	*1,429,696.86*	*10,255,224.89*	*18,729,949.86*	*18,729,949.86*
0603 Wildlife Facilities & Sanctuary	**1.00**	**EA**	**4,705,322**	**1,429,697**	**10,255,225**	**18,729,950**	**18,729,950**
			4,705,322.36	*1,429,696.86*	*10,255,224.89*	*18,729,949.86*	*18,729,949.86*
060373 Habitat and Feeding Facilities	**1.00**	**EA**	**4,705,322**	**1,429,697**	**10,255,225**	**18,729,950**	**18,729,950**
			4,642,997.36	*1,429,696.86*	*10,255,224.89*	*16,327,919.11*	*16,327,919.11*
Contract 1-Wetland Restoration & Reef Habitat Constriction	**1.00**	**EA**	**4,642,997**	**1,429,697**	**10,255,225**	**16,327,919**	**16,327,919**
			219,865.87	*76,119.10*	*297,293.69*	*593,278.65*	*593,278.65*
Wetland Restoration w/Phragmites Removal	**1.00**	**EA**	**219,866**	**76,119**	**297,294**	**593,279**	**593,279**
			40,772.92	*12,201.88*	*53,941.04*	*106,915.84*	*106,915.84*
PA Princess Anne HS	**3.82**	**ACR**	**155,549**	**46,550**	**205,785**	**407,884**	**407,884**
			142,852.54	*46,531.79*	*182,496.10*	*371,880.43*	*371,880.43*
Construction	**1.00**	**EA**	**142,853**	**46,532**	**182,496**	**371,880**	**371,880**
			1,485.63	*5,139.78*	*0.00*	*6,625.41*	*6,625.41*
Mob	**1.00**	**EA**	**1,486**	**5,140**	**0**	**6,625**	**6,625**
			0.00	*20.20*	*0.00*	*20.20*	*20.20*
NAO L50Z4640 LOADER/BACKHOE, WHEEL, 0.80 CY (0.6 M3) FRONT END BUCKET, 9.8' (3.0 M) DEPTH OF HOE, 24" (0.61 M) DIPPER, 4X4	12.00	HR	0	242	0	242	242
			0.00	*109.52*	*0.00*	*109.52*	*109.52*
NAO T15Z6520 TRACTOR, CRAWLER (DOZER), 181-250 HP (135-186 KW), POWERSHIFT, LGP, W/UNIVERSAL BLADE	12.00	HR	0	1,314	0	1,314	1,314
			30.95	*0.00*	*0.00*	*30.95*	*30.95*
MIL B-TRKDVRHV Truck Drivers, Heavy	48.00	HR	1,486	0	0	1,486	1,486
			0.00	*33.88*	*0.00*	*33.88*	*33.88*
NAO T15Z6440 TRACTOR, CRAWLER (DOZER), 76-100 HP (57-75 KW), POWERSHIFT, W/UNIVERSAL BLADE	12.00	HR	0	407	0	407	407
			0.00	*8.91*	*0.00*	*8.91*	*8.91*
EP T45XX016 TRUCK TRAILER, LOWBOY, 50 TON, 3 AXLE (ADD TOWING TRUCK)	48.00	HR	0	428	0	428	428
			0.00	*77.86*	*0.00*	*77.86*	*77.86*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
NAO L35Z4260 LOADER, FRONT END, CRAWLER, 2.60 CY (2.0 M3) BUCKET	12.00	HR	0	934	0	934	934
			0.00	*37.80*	*0.00*	*37.80*	*37.80*
MAP T50XX028 TRUCK, HIGHWAY, 45,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	48.00	HR	0	1,814	0	1,814	1,814
			2,247.97	*2,016.32*	*7,280.48*	*11,544.76*	*11,544.76*
Clearing, Demo, and Misc	**1.00**	**EA**	**2,248**	**2,016**	**7,280**	**11,545**	**11,545**
			332.53	*584.09*	*0.00*	*916.62*	*916.62*
RSM 311313100400 Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	3.00	ACR	998	1,752	0	2,750	2,750
			96.80	*48.40*	*1,107.54*	*1,252.74*	*1,252.74*
USR Herbicide -Wetlands area	3.82	ACR	370	185	4,231	4,785	4,785
USR Misc	1.00	LS	150	50	315	515	515
			2.13	*0.26*	*10.45*	*12.84*	*12.84*
RSM 015523500100 Temporary, roads, gravel fill, 8" gravel depth, excl surfacing	111.00	SY	236	29	1,160	1,425	1,425
			6.60	*0.00*	*21.00*	*27.60*	*27.60*
USR 022661120 Tubidity barrier, floating	75.00	LF	495	0	1,575	2,070	2,070
			2.05	*1.49*	*0.95*	*4.49*	*4.49*
Earthwork	**26,500.00**	**CY**	**54,291**	**39,376**	**25,200**	**118,867**	**118,867**
			1.97	*1.36*	*0.00*	*3.32*	*3.32*
HNC 312316400020 Excavate and fill, 75 H.P. dozer, move 150', stockpile	26,500.00	BCY	52,107	35,915	0	88,022	88,022
			1.09	*1.73*	*12.60*	*15.42*	*15.42*
RSM 312323170170 Fill, from stockpile, 130 H.P., 2-1/2 C.Y., 300' haul, spread fill, with front-end loader, excludes compaction; Sand	2,000.00	LCY	2,185	3,460	25,200	30,845	30,845
			22,323.03	*0.00*	*39,477.80*	*61,800.82*	*61,800.82*
Landscaping	**3.80**	**ACR**	**84,828**	**0**	**150,016**	**234,843**	**234,843**
			0.60	*0.00*	*1.37*	*1.97*	*1.97*
USR Spartina Alterniflora 18" spacing, 1/2 area	42,461.20	EA	25,477	0	57,960	83,436	83,436
			0.60	*0.00*	*1.37*	*1.97*	*1.97*
USR Spartina Patens 18" spacing, 1/2 area	42,461.20	EA	25,477	0	57,960	83,436	83,436
			0.00	*0.00*	*14.70*	*14.70*	*14.70*
USR Wetland Shrubs -1 gallon; 5' oc (1/4 area)	1,912.35	EA	0	0	28,112	28,112	28,112
			7.78	*0.00*	*0.00*	*7.78*	*7.78*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only; (1/4 area)	1,912.35	EA	14,874	0	0	14,874	14,874
			5,000.00	*0.00*	*1,575.00*	*6,575.00*	*6,575.00*
USR Goose Fencing	3.80	ACR	19,000	0	5,985	24,985	24,985
			12,696.13	*18.39*	*23,288.96*	*36,003.48*	*36,003.48*
Adapt Mngmt-Wetlands	**1.00**	**EA**	**12,696**	**18**	**23,289**	**36,003**	**36,003**
			96.80	*48.40*	*1,107.54*	*1,252.74*	*1,252.74*
Herbicide	**0.38**	**ACR**	**37**	**18**	**421**	**476**	**476**
			96.80	*48.40*	*1,107.54*	*1,252.74*	*1,252.74*
USR Herbicide -Wetlalnds area	0.38	ACR	37	18	421	476	476
			18,408.80	*0.00*	*32,080.02*	*50,488.82*	*50,488.82*
Wetlands Plantings	**0.39**	**ACR**	**7,179**	**0**	**12,511**	**19,691**	**19,691**
			0.60	*0.00*	*1.37*	*1.97*	*1.97*
USR Spartina Alterniflora-18" spacing, 1/2 area	4,357.86	EA	2,615	0	5,948	8,563	8,563
			0.60	*0.00*	*1.37*	*1.97*	*1.97*
USR Spartina Patens-18" spacing, 1/2 area	4,357.86	EA	2,615	0	5,948	8,563	8,563
			5,000.00	*0.00*	*1,575.00*	*6,575.00*	*6,575.00*
USR Goose Fencing	0.39	ACR	1,950	0	614	2,564	2,564
			15,656.91	*0.00*	*29,591.10*	*45,248.01*	*45,248.01*
Shrubs	**0.35**	**ACR**	**5,480**	**0**	**10,357**	**15,837**	**15,837**
			0.00	*0.00*	*14.70*	*14.70*	*14.70*
USR Wetland Shrubs -1 gallon; 5' oc	704.55	EA	0	0	10,357	10,357	10,357
			7.78	*0.00*	*0.00*	*7.78*	*7.78*
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only	704.55	EA	5,480	0	0	5,480	5,480
			2,680.57	*1,160.82*	*2,422.80*	*6,264.19*	*6,264.19*
SG South Great Neck	**13.71**	**ACR**	**36,756**	**15,917**	**33,221**	**85,895**	**85,895**
			34,077.88	*15,908.95*	*28,002.61*	*77,989.44*	*77,989.44*
Construction	**1.00**	**EA**	**34,078**	**15,909**	**28,003**	**77,989**	**77,989**
			495.21	*1,713.26*	*0.00*	*2,208.47*	*2,208.47*
Mob	**1.00**	**EA**	**495**	**1,713**	**0**	**2,208**	**2,208**
			30.95	*0.00*	*0.00*	*30.95*	*30.95*
MIL B-TRKDVRHV Truck Drivers, Heavy	16.00	HR	495	0	0	495	495
			0.00	*77.86*	*0.00*	*77.86*	*77.86*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
NAO L35Z4260 LOADER, FRONT END, CRAWLER, 2.60 CY (2.0 M3) BUCKET	4.00	HR	0	311	0	311	311
			0.00	*20.20*	*0.00*	*20.20*	*20.20*
NAO L50Z4640 LOADER/BACKHOE, WHEEL, 0.80 CY (0.6 M3) FRONT END BUCKET, 9.8' (3.0 M) DEPTH OF HOE, 24" (0.61 M) DIPPER, 4X4	4.00	HR	0	81	0	81	81
			0.00	*33.88*	*0.00*	*33.88*	*33.88*
NAO T15Z6440 TRACTOR, CRAWLER (DOZER), 76-100 HP (57-75 KW), POWERSHIFT, W/UNIVERSAL BLADE	4.00	HR	0	136	0	136	136
			0.00	*109.52*	*0.00*	*109.52*	*109.52*
NAO T15Z6520 TRACTOR, CRAWLER (DOZER), 181-250 HP (135-186 KW), POWERSHIFT, LGP, W/UNIVERSAL BLADE	4.00	HR	0	438	0	438	438
			0.00	*8.91*	*0.00*	*8.91*	*8.91*
EP T45XX016 TRUCK TRAILER, LOWBOY, 50 TON, 3 AXLE (ADD TOWING TRUCK)	16.00	HR	0	143	0	143	143
			0.00	*37.80*	*0.00*	*37.80*	*37.80*
MAP T50XX028 TRUCK, HIGHWAY, 45,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	16.00	HR	0	605	0	605	605
			1,048.22	*663.26*	*2,524.67*	*4,236.15*	*4,236.15*
Clearing, Demo, and Misc	**1.00**	**EA**	**1,048**	**663**	**2,525**	**4,236**	**4,236**
			332.53	*584.09*	*0.00*	*916.62*	*916.62*
RSM 311313100400 Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	1.00	ACR	333	584	0	917	917
USR Misc	1.00	LS	150	50	315	515	515
			2.13	*0.26*	*10.45*	*12.84*	*12.84*
RSM 015523500100 Temporary, roads, gravel fill, 8" gravel depth, excl surfacing	111.00	SY	236	29	1,160	1,425	1,425
			6.60	*0.00*	*21.00*	*27.60*	*27.60*
USR 022661120 Tubidity barrier, floating	50.00	LF	330	0	1,050	1,380	1,380
			1.97	*1.36*	*0.00*	*3.32*	*3.32*
Excavation	**9,500.00**	**CY**	**18,680**	**12,875**	**0**	**31,555**	**31,555**
			1.97	*1.36*	*0.00*	*3.32*	*3.32*
HNC 312316400020 Excavate and fill, 75 H.P. dozer, move 150', stockpile	9,500.00	BCY	18,680	12,875	0	31,555	31,555
			16,091.40	*763.18*	*29,591.10*	*46,445.68*	*46,445.68*
Landscaping .861 AC	**0.86**	**ACR**	**13,855**	**657**	**25,478**	**39,990**	**39,990**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
RSM 329113232700 Soil preparation, structural soil mixing, rough grade & scarify subsoil to receive topsoil, clay and till, 149 kW dozer with scarifier	37.50	MSF	*9.98* 374	*17.52* 657	*0.00* 0	*27.50* 1,031	*27.50* 1,031
USR Wetland Shrubs -1 gallon; 5' oc	1,733.19	EA	*0.00* 0	*0.00* 0	*14.70* 25,478	*14.70* 25,478	*14.70* 25,478
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only	1,733.19	EA	*7.78* 13,481	*0.00* 0	*0.00* 0	*7.78* 13,481	*7.78* 13,481
Adapt Mngmt-Wetlands	**1.00**	**EA**	*2,678.13* **2,678**	*8.23* **8**	*5,218.77* **5,219**	*7,905.13* **7,905**	*7,905.13* **7,905**
Herbicide	**0.17**	**ACR**	*96.80* **16**	*48.40* **8**	*1,107.54* **188**	*1,252.74* **213**	*1,252.74* **213**
USR Herbicide -Wetlalnds area	0.17	ACR	*96.80* 16	*48.40* 8	*1,107.54* 188	*1,252.74* 213	*1,252.74* 213
Shrubs	**0.17**	**ACR**	*15,656.91* **2,662**	*0.00* **0**	*29,591.10* **5,030**	*45,248.01* **7,692**	*45,248.01* **7,692**
USR Wetland Shrubs -1 gallon; 5' oc	342.21	EA	*0.00* 0	*0.00* 0	*14.70* 5,030	*14.70* 5,030	*14.70* 5,030
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only	342.21	EA	*7.78* 2,662	*0.00* 0	*0.00* 0	*7.78* 2,662	*7.78* 2,662
MD Mill Dam Creek	**0.96**	**ACR**	*4,536.40* **4,350**	*4,338.73* **4,161**	*4,093.69* **3,926**	*12,968.82* **12,437**	*12,968.82* **12,437**
Construction	**1.00**	**EA**	*4,018.71* **4,019**	*4,159.39* **4,159**	*3,271.21* **3,271**	*11,449.31* **11,449**	*11,449.31* **11,449**
Mob	**1.00**	**EA**	*495.21* **495**	*1,713.26* **1,713**	*0.00* **0**	*2,208.47* **2,208**	*2,208.47* **2,208**
MIL B-TRKDVRHV Truck Drivers, Heavy	16.00	HR	*30.95* 495	*0.00* 0	*0.00* 0	*30.95* 495	*30.95* 495
NAO L35Z4260 LOADER, FRONT END, CRAWLER, 2.60 CY (2.0 M3) BUCKET	4.00	HR	*0.00* 0	*77.86* 311	*0.00* 0	*77.86* 311	*77.86* 311
NAO L50Z4640 LOADER/BACKHOE, WHEEL, 0.80 CY (0.6 M3) FRONT END BUCKET, 9.8' (3.0 M) DEPTH OF HOE, 24" (0.61 M) DIPPER, 4X4	4.00	HR	*0.00* 0	*20.20* 81	*0.00* 0	*20.20* 81	*20.20* 81

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
NAO T15Z6440 TRACTOR, CRAWLER (DOZER), 76-100 HP (57-75 KW), POWERSHIFT, W/UNIVERSAL BLADE	4.00	HR	*0.00* 0	*33.88* 136	*0.00* 0	*33.88* 136	*33.88* 136
NAO T15Z6520 TRACTOR, CRAWLER (DOZER), 181-250 HP (135-186 KW), POWERSHIFT, LGP, W/UNIVERSAL BLADE	4.00	HR	*0.00* 0	*109.52* 438	*0.00* 0	*109.52* 438	*109.52* 438
EP T45XX016 TRUCK TRAILER, LOWBOY, 50 TON, 3 AXLE (ADD TOWING TRUCK)	16.00	HR	*0.00* 0	*8.91* 143	*0.00* 0	*8.91* 143	*8.91* 143
MAP T50XX028 TRUCK, HIGHWAY, 45,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	16.00	HR	*0.00* 0	*37.80* 605	*0.00* 0	*37.80* 605	*37.80* 605
Clearing, Demo, and Misc	**1.00**	**EA**	*762.95* **763**	*356.50* **356**	*1,939.61* **1,940**	*3,059.06* **3,059**	*3,059.06* **3,059**
RSM 311313100400 Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	0.50	ACR	*332.53* 166	*584.09* 292	*0.00* 0	*916.62* 458	*916.62* 458
RSM 015523500100 Temporary, roads, gravel fill, 8" gravel depth, excl surfacing	55.00	SY	*2.13* 117	*0.26* 14	*10.45* 575	*12.84* 706	*12.84* 706
USR Misc	1.00	LS	150	50	315	515	515
USR 022661120 Tubidity barrier, floating	50.00	LF	*6.60* 330	*0.00* 0	*21.00* 1,050	*27.60* 1,380	*27.60* 1,380
Excavation	**600.00**	**CY**	*1.97* **1,180**	*1.36* **813**	*0.00* **0**	*3.32* **1,993**	*3.32* **1,993**
HNC 312316400020 Excavate and fill, 75 H.P. dozer, move 150', stockpile	600.00	BCY	*1.97* 1,180	*1.36* 813	*0.00* 0	*3.32* 1,993	*3.32* 1,993
Load and Haul	**300.00**	**CY**	*2.85* **856**	*4.14* **1,241**	*0.00* **0**	*6.99* **2,098**	*6.99* **2,098**
HNC 312316440325 Excavate and load, bank measure, medium material, 2-3/4 C.Y. bucket, track loader; assume 1500 cy - hauled off	300.00	BCY	*0.38* 113	*0.60* 180	*0.00* 0	*0.98* 293	*0.98* 293
RSM 312323180100 Hauling, excavated or borrow material, loose cubic yards, 2 mile round trip, 2.6 loads/hour, 6 C.Y. dump truck, highway haulers, excludes loading	300.00	LCY	*2.48* 743	*3.54* 1,062	*0.00* 0	*6.02* 1,805	*6.02* 1,805

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Landscaping	**0.05**	**ACR**	*16,100.29* **725**	*778.78* **35**	*29,591.10* **1,332**	*46,470.17* **2,091**	*46,470.17* **2,091**
RSM 329113232700 Soil preparation, structural soil mixing, rough grade & scarify subsoil to receive topsoil, clay and till, 149 kW dozer with scarifier	2.00	MSF	*9.98* 20	*17.52* 35	*0.00* 0	*27.50* 55	*27.50* 55
USR Wetland Shrubs -1 gallon; 5' oc (1/4 area)	90.59	EA	*0.00* 0	*0.00* 0	*14.70* 1,332	*14.70* 1,332	*14.70* 1,332
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only; (1/4 area)	90.59	EA	*7.78* 705	*0.00* 0	*0.00* 0	*7.78* 705	*7.78* 705
Adapt Mngmt-Wetlands	**1.00**	**EA**	*331.70* **332**	*1.45* **1**	*654.64* **655**	*987.79* **988**	*987.79* **988**
Herbicide	**0.03**	**ACR**	*96.80* **3**	*48.40* **1**	*1,107.54* **33**	*1,252.74* **38**	*1,252.74* **38**
USR Herbicide -Wetlalnds area	0.03	ACR	*96.80* 3	*48.40* 1	*1,107.54* 33	*1,252.74* 38	*1,252.74* 38
Shrubs	**0.02**	**ACR**	*15,656.91* **329**	*0.00* **0**	*29,591.10* **621**	*45,248.01* **950**	*45,248.01* **950**
USR Wetland Shrubs -1 gallon; 5' oc	42.27	EA	*0.00* 0	*0.00* 0	*14.70* 621	*14.70* 621	*14.70* 621
RSM 329343100730 Planting, trees, shrubs, and ground cover, heavy or stony soil, container, 1 gallon, includes planting only	42.27	EA	*7.78* 329	*0.00* 0	*0.00* 0	*7.78* 329	*7.78* 329
NG North Great Neck	**19.89**	**ACR**	*1,167.07* **23,211**	*477.22* **9,491**	*2,733.38* **54,361**	*4,377.67* **87,063**	*4,377.67* **87,063**
Construction	**1.00**	**EA**	*19,686.97* **19,687**	*9,477.82* **9,478**	*47,967.17* **47,967**	*77,131.95* **77,132**	*77,131.95* **77,132**
Mob	**1.00**	**EA**	*495.21* **495**	*1,713.26* **1,713**	*0.00* **0**	*2,208.47* **2,208**	*2,208.47* **2,208**
MIL B-TRKDVRHV Truck Drivers, Heavy	16.00	HR	*30.95* 495	*0.00* 0	*0.00* 0	*30.95* 495	*30.95* 495
NAO L35Z4260 LOADER, FRONT END, CRAWLER, 2.60 CY (2.0 M3) BUCKET	4.00	HR	*0.00* 0	*77.86* 311	*0.00* 0	*77.86* 311	*77.86* 311

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
NAO L50Z4640 LOADER/BACKHOE, WHEEL, 0.80 CY (0.6 M3) FRONT END BUCKET, 9.8' (3.0 M) DEPTH OF HOE, 24" (0.61 M) DIPPER, 4X4	4.00	HR	*0.00* 0	*20.20* 81	*0.00* 0	*20.20* 81	*20.20* 81
NAO T15Z6440 TRACTOR, CRAWLER (DOZER), 76-100 HP (57-75 KW), POWERSHIFT, W/UNIVERSAL BLADE	4.00	HR	*0.00* 0	*33.88* 136	*0.00* 0	*33.88* 136	*33.88* 136
NAO T15Z6520 TRACTOR, CRAWLER (DOZER), 181-250 HP (135-186 KW), POWERSHIFT, LGP, W/UNIVERSAL BLADE	4.00	HR	*0.00* 0	*109.52* 438	*0.00* 0	*109.52* 438	*109.52* 438
EP T45XX016 TRUCK TRAILER, LOWBOY, 50 TON, 3 AXLE (ADD TOWING TRUCK)	16.00	HR	*0.00* 0	*8.91* 143	*0.00* 0	*8.91* 143	*8.91* 143
MAP T50XX028 TRUCK, HIGHWAY, 45,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	16.00	HR	*0.00* 0	*37.80* 605	*0.00* 0	*37.80* 605	*37.80* 605
Clearing, Demo, and Misc	**1.00**	**EA**	*1,380.76* **1,381**	*1,247.34* **1,247**	*2,524.67* **2,525**	*5,152.77* **5,153**	*5,152.77* **5,153**
RSM 311313100400 Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	2.00	ACR	*332.53* 665	*584.09* 1,168	*0.00* 0	*916.62* 1,833	*916.62* 1,833
USR Misc	1.00	LS	150	50	315	515	515
RSM 015523500100 Temporary, roads, gravel fill, 8" gravel depth, excl surfacing	111.00	SY	*2.13* 236	*0.26* 29	*10.45* 1,160	*12.84* 1,425	*12.84* 1,425
USR 022661120 Tubidity barrier, floating	50.00	LF	*6.60* 330	*0.00* 0	*21.00* 1,050	*27.60* 1,380	*27.60* 1,380
Earthwork	**1,900.00**	**CY**	*3.12* **5,921**	*3.18* **6,035**	*13.26* **25,200**	*19.56* **37,156**	*19.56* **37,156**
HNC 312316400020 Excavate and fill, 75 H.P. dozer, move 150', stockpile	1,900.00	BCY	*1.97* 3,736	*1.36* 2,575	*0.00* 0	*3.32* 6,311	*3.32* 6,311
RSM 312323170170 Fill, from stockpile, 130 H.P., 2-1/2 C.Y., 300' haul, spread fill, with front-end loader, excludes compaction; Sand	2,000.00	LCY	*1.09* 2,185	*1.73* 3,460	*12.60* 25,200	*15.42* 30,845	*15.42* 30,845
Landscaping	**0.63**	**ACR**	*18,843.57* **11,890**	*763.66* **482**	*32,080.02* **20,242**	*51,687.25* **32,615**	*51,687.25* **32,615**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
RSM 329113232700 Soil preparation, structural soil mixing, rough grade & scarify subsoil to receive topsoil, clay and till, 149 kW dozer with scarifier	27.50	MSF	*9.98* 274	*17.52* 482	*0.00* 0	*27.50* 756	*27.50* 756
USR Spartina Alterniflora 18" spacing, full area	14,101.59	EA	*0.60* 8,461	*0.00* 0	*1.37* 19,249	*1.97* 27,710	*1.97* 27,710
USR Goose Fencing	0.63	ACR	*5,000.00* 3,155	*0.00* 0	*1,575.00* 994	*6,575.00* 4,149	*6,575.00* 4,149
Adapt Mngmt-Wetlands	**1.00**	**EA**	*3,523.81* **3,524**	*13.07* **13**	*6,394.24* **6,394**	*9,931.12* **9,931**	*9,931.12* **9,931**
Herbicide	**0.27**	**ACR**	*96.80* **26**	*48.40* **13**	*1,107.54* **299**	*1,252.74* **338**	*1,252.74* **338**
USR Herbicide -Wetlalnds area	0.27	ACR	*96.80* 26	*48.40* 13	*1,107.54* 299	*1,252.74* 338	*1,252.74* 338
Wetlands Plantings	**0.19**	**ACR**	*18,408.80* **3,498**	*0.00* **0**	*32,080.02* **6,095**	*50,488.82* **9,593**	*50,488.82* **9,593**
USR Spartina Alterniflora-18" spacing, 1/2 area	4,246.12	EA	*0.60* 2,548	*0.00* 0	*1.37* 5,796	*1.97* 8,344	*1.97* 8,344
USR Goose Fencing	0.19	ACR	*5,000.00* 950	*0.00* 0	*1,575.00* 299	*6,575.00* 1,249	*6,575.00* 1,249
Essential Fish Habitat (EFH)	**1.00**	**EA**	*4,423,131.49* **4,423,131**	*1,353,577.76* **1,353,578**	*9,957,931.20* **9,957,931**	*15,734,640.45* **15,734,640**	*15,734,640.45* **15,734,640**
Reef Habitat Construction -Phase 1	**1.00**	**EA**	*1,618,372.84* **1,618,373**	*476,186.50* **476,187**	*3,317,797.00* **3,317,797**	*5,412,356.34* **5,412,356**	*5,412,356.34* **5,412,356**
EFH Bay Balls	**7,046.00**	**EA**	*52.94* **373,044**	*18.99* **133,832**	*94.50* **665,847**	*166.44* **1,172,722**	*166.44* **1,172,722**
Bay Ball EFH-1	**809.00**	**EA**	*52.03* **42,088**	*18.76* **15,178**	*94.50* **76,451**	*165.29* **133,717**	*165.29* **133,717**
USR Bay Ball-Material	809.00	EA	*0.00* 0	*0.00* 0	*94.50* 76,451	*94.50* 76,451	*94.50* 76,451
USR StkBy Unload Bay Balls & Stockpile	809.00	EA	*2.73* 2,208	*1.86* 1,502	*0.00* 0	*4.58* 3,709	*4.58* 3,709
USR TkBy Transport Bay Balls-Truck	809.00	EA	*2.81* 2,276	*3.96* 3,203	*0.00* 0	*6.77* 5,479	*6.77* 5,479
USR LdBy Load Bay Balls onto Truck @ Plant	809.00	EA	*2.73* 2,208	*1.86* 1,502	*0.00* 0	*4.58* 3,709	*4.58* 3,709

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			18.46	*5.32*	*0.00*	*23.78*	*23.78*
USR BrgBy1 Load Bay Balls into Barge EFH-1	809.00	EA	14,934	4,307	0	19,242	19,242
			25.29	*5.77*	*0.00*	*31.06*	*31.06*
USR PlcBy1 Transport Bay Ball by Barge & Place- Site RH-1	809.00	EA	20,463	4,664	0	25,127	25,127
			52.36	*18.85*	*94.50*	*165.70*	*165.70*
Bay Ball EFH-2	**4,577.00**	**EA**	**239,642**	**86,255**	**432,527**	**758,424**	**758,424**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	4,577.00	EA	0	0	432,527	432,527	432,527
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	4,577.00	EA	12,489	8,496	0	20,985	20,985
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	4,577.00	EA	12,878	18,121	0	31,000	31,000
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	4,577.00	EA	12,489	8,496	0	20,985	20,985
			18.60	*5.36*	*0.00*	*23.97*	*23.97*
USR BrgBy2 Load Bay Balls into Barge EFH-2	4,577.00	EA	85,134	24,555	0	109,689	109,689
			25.49	*5.81*	*0.00*	*31.30*	*31.30*
USR PlcBy2 Transport Bay Ball by Barge & Place- Site RH-2	4,577.00	EA	116,651	26,587	0	143,238	143,238
			54.50	*19.39*	*94.50*	*168.39*	*168.39*
Bay Ball EFH-3	**643.00**	**EA**	**35,045**	**12,467**	**60,764**	**108,276**	**108,276**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	643.00	EA	0	0	60,764	60,764	60,764
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	643.00	EA	1,755	1,194	0	2,948	2,948
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	643.00	EA	1,809	2,546	0	4,355	4,355
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	643.00	EA	1,755	1,194	0	2,948	2,948
			19.51	*5.63*	*0.00*	*25.13*	*25.13*
USR BrgBy3 Load Bay Balls into Barge EFH-3	643.00	EA	12,542	3,617	0	16,159	16,159
			26.73	*6.09*	*0.00*	*32.82*	*32.82*
USR PlcBy3 Transport Bay Ball by Barge & Place- Site RH-3	643.00	EA	17,185	3,917	0	21,102	21,102
			55.33	*19.60*	*94.50*	*169.43*	*169.43*
Bay Ball EFH-4	**1,017.00**	**EA**	**56,269**	**19,931**	**96,107**	**172,306**	**172,306**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	1,017.00	EA	0	0	96,107	96,107	96,107

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR StkBy Unload Bay Balls & Stockpile	1,017.00	EA	*2.73* 2,775	*1.86* 1,888	*0.00* 0	*4.58* 4,663	*4.58* 4,663
USR TkBy Transport Bay Balls-Truck	1,017.00	EA	*2.81* 2,862	*3.96* 4,027	*0.00* 0	*6.77* 6,888	*6.77* 6,888
USR LdBy Load Bay Balls onto Truck @ Plant	1,017.00	EA	*2.73* 2,775	*1.86* 1,888	*0.00* 0	*4.58* 4,663	*4.58* 4,663
USR BrgBy4 Load Bay Balls into Barge EFH-4	1,017.00	EA	*19.85* 20,191	*5.73* 5,824	*0.00* 0	*25.58* 26,015	*25.58* 26,015
USR PlcBy4 Transport Bay Ball by Barge & Place- Site RH-4	1,017.00	EA	*27.20* 27,666	*6.20* 6,306	*0.00* 0	*33.40* 33,971	*33.40* 33,971
EFH Large Balls Normal Foundation	**5,061.00**	**EA**	*50.06* **253,365**	*18.92* **95,759**	*153.26* **775,632**	*222.24* **1,124,756**	*222.24* **1,124,756**
Goliath	**674.00**	**EA**	*156.23* **105,298**	*61.58* **41,504**	*505.04* **340,396**	*722.85* **487,198**	*722.85* **487,198**
EFH-5, 6, & 7	**390.00**	**EA**	*160.11* **62,441**	*66.52* **25,942**	*505.79* **197,260**	*732.42* **285,644**	*732.42* **285,644**
Mob	**1.00**	**EA**	*6,586.79* **6,587**	*5,333.28* **5,333**	*700.00* **700**	*12,620.07* **12,620**	*12,620.07* **12,620**
Mob Marine equipment and Cranes	**1.00**	**EA**	*6,586.79* **6,587**	*5,333.28* **5,333**	*700.00* **700**	*12,620.07* **12,620**	*12,620.07* **12,620**
USR WtrMb Mob Marine Equipment & Cranes	16.00	HR	*411.67* 6,587	*333.33* 5,333	*0.00* 0	*745.00* 11,920	*745.00* 11,920
USR Misc Mob work	1.00	LS	0	0	700	700	700
Load & Place Reef Balls	**390.00**	**EA**	*143.22* **55,854**	*52.84* **20,609**	*504.00* **196,560**	*700.06* **273,023**	*700.06* **273,023**
USR Goliath Reef Ball-Material	390.00	EA	*0.00* 0	*0.00* 0	*504.00* 196,560	*504.00* 196,560	*504.00* 196,560
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	390.00	EA	*50.75* 19,791	*14.64* 5,708	*0.00* 0	*65.38* 25,499	*65.38* 25,499
USR LdLg Load Large Balls onto Truck @ Plant	390.00	EA	*6.82* 2,661	*4.64* 1,810	*0.00* 0	*11.46* 4,470	*11.46* 4,470
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	390.00	EA	*69.53* 27,117	*15.85* 6,181	*0.00* 0	*85.38* 33,298	*85.38* 33,298

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	390.00	EA	2,661	1,810	0	4,470	4,470
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	390.00	EA	3,625	5,101	0	8,725	8,725
			149.52	*54.44*	*504.00*	*707.96*	*707.96*
EFH-8	**238.00**	**EA**	**35,586**	**12,957**	**119,952**	**168,495**	**168,495**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	238.00	EA	0	0	119,952	119,952	119,952
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	238.00	EA	1,624	1,104	0	2,728	2,728
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	238.00	EA	2,212	3,113	0	5,325	5,325
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	238.00	EA	1,624	1,104	0	2,728	2,728
			53.41	*15.40*	*0.00*	*68.81*	*68.81*
USR BrgBy8 Load Large Balls into Barge RH-8	238.00	EA	12,710	3,666	0	16,376	16,376
			73.18	*16.68*	*0.00*	*89.85*	*89.85*
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	238.00	EA	17,416	3,969	0	21,385	21,385
			158.08	*56.61*	*504.00*	*718.69*	*718.69*
EFH-9	**46.00**	**EA**	**7,271**	**2,604**	**23,184**	**33,060**	**33,060**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	46.00	EA	0	0	23,184	23,184	23,184
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	314	213	0	527	527
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	428	602	0	1,029	1,029
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	46.00	EA	314	213	0	527	527
			57.02	*16.44*	*0.00*	*73.46*	*73.46*
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	2,623	756	0	3,379	3,379
			78.12	*17.81*	*0.00*	*95.93*	*95.93*
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	3,594	819	0	4,413	4,413
			146.46	*53.67*	*451.50*	*651.62*	*651.62*
Super	**674.00**	**EA**	**98,711**	**36,170**	**304,311**	**439,193**	**439,193**
			143.22	*52.84*	*451.50*	*647.56*	*647.56*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
EFH-5, 6, & 7	**390.00**	**EA**	**55,854**	**20,609**	**176,085**	**252,548**	**252,548**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	390.00	EA	0	0	176,085	176,085	176,085
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	390.00	EA	2,661	1,810	0	4,470	4,470
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	390.00	EA	3,625	5,101	0	8,725	8,725
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	390.00	EA	2,661	1,810	0	4,470	4,470
			50.75	*14.64*	*0.00*	*65.38*	*65.38*
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	390.00	EA	19,791	5,708	0	25,499	25,499
			69.53	*15.85*	*0.00*	*85.38*	*85.38*
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	390.00	EA	27,117	6,181	0	33,298	33,298
			149.52	*54.44*	*451.50*	*655.46*	*655.46*
EFH-8	**238.00**	**EA**	**35,586**	**12,957**	**107,457**	**156,000**	**156,000**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	238.00	EA	0	0	107,457	107,457	107,457
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	238.00	EA	1,624	1,104	0	2,728	2,728
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	238.00	EA	2,212	3,113	0	5,325	5,325
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	238.00	EA	1,624	1,104	0	2,728	2,728
			53.41	*15.40*	*0.00*	*68.81*	*68.81*
USR BrgBy8 Load Large Balls into Barge RH-8	238.00	EA	12,710	3,666	0	16,376	16,376
			73.18	*16.68*	*0.00*	*89.85*	*89.85*
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	238.00	EA	17,416	3,969	0	21,385	21,385
			158.08	*56.61*	*451.50*	*666.19*	*666.19*
EFH-9	**46.00**	**EA**	**7,271**	**2,604**	**20,769**	**30,645**	**30,645**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	46.00	EA	0	0	20,769	20,769	20,769
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	314	213	0	527	527
			9.29	*13.08*	*0.00*	*22.37*	*22.37*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	428	602	0	1,029	1,029
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	46.00	EA	314	213	0	527	527
			57.02	*16.44*	*0.00*	*73.46*	*73.46*
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	2,623	756	0	3,379	3,379
			78.12	*17.81*	*0.00*	*95.93*	*95.93*
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	3,594	819	0	4,413	4,413
			146.46	*53.67*	*388.50*	*588.62*	*588.62*
Ultra	**337.00**	**EA**	**49,356**	**18,085**	**130,925**	**198,365**	**198,365**
			143.22	*52.84*	*388.50*	*584.56*	*584.56*
EFH-5, 6, & 7	**195.00**	**EA**	**27,927**	**10,305**	**75,758**	**113,989**	**113,989**
			0.00	*0.00*	*388.50*	*388.50*	*388.50*
USR Ultra Reef Ball-Material	195.00	EA	0	0	75,758	75,758	75,758
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	195.00	EA	1,330	905	0	2,235	2,235
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	195.00	EA	1,812	2,550	0	4,363	4,363
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	195.00	EA	1,330	905	0	2,235	2,235
			50.75	*14.64*	*0.00*	*65.38*	*65.38*
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	195.00	EA	9,895	2,854	0	12,750	12,750
			69.53	*15.85*	*0.00*	*85.38*	*85.38*
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	195.00	EA	13,559	3,090	0	16,649	16,649
			149.52	*54.44*	*388.50*	*592.46*	*592.46*
EFH-8	**119.00**	**EA**	**17,793**	**6,479**	**46,232**	**70,503**	**70,503**
			0.00	*0.00*	*388.50*	*388.50*	*388.50*
USR Ultra Reef Ball-Material	119.00	EA	0	0	46,232	46,232	46,232
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	119.00	EA	812	552	0	1,364	1,364
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	119.00	EA	1,106	1,556	0	2,662	2,662
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	119.00	EA	812	552	0	1,364	1,364
			53.41	*15.40*	*0.00*	*68.81*	*68.81*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR BrgBy8 Load Large Balls into Barge RH-8	119.00	EA	6,355	1,833	0	8,188	8,188
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	119.00	EA	*73.18* 8,708	*16.68* 1,985	*0.00* 0	*89.85* 10,693	*89.85* 10,693
EFH-9	**23.00**	**EA**	*158.08* **3,636**	*56.61* **1,302**	*388.50* **8,936**	*603.19* **13,873**	*603.19* **13,873**
USR Ultra Reef Ball-Material	23.00	EA	*0.00* 0	*0.00* 0	*388.50* 8,936	*388.50* 8,936	*388.50* 8,936
USR LdLg Load Large Balls onto Truck @ Plant	23.00	EA	*6.82* 157	*4.64* 107	*0.00* 0	*11.46* 264	*11.46* 264
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	23.00	EA	*9.29* 214	*13.08* 301	*0.00* 0	*22.37* 515	*22.37* 515
USR StkLg Unload Large Balls & Stockpile	23.00	EA	*6.82* 157	*4.64* 107	*0.00* 0	*11.46* 264	*11.46* 264
USR BrgBy9 Load Large Balls into Barge RH-9	23.00	EA	*57.02* 1,311	*16.44* 378	*0.00* 0	*73.46* 1,690	*73.46* 1,690
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	23.00	EA	*78.12* 1,797	*17.81* 410	*0.00* 0	*95.93* 2,206	*95.93* 2,206
EFH Large Balls Soft Foundation	**1,788.00**	**EA**	*312.54* **558,814**	*95.76* **171,215**	*1,049.40* **1,876,319**	*1,457.69* **2,606,347**	*1,457.69* **2,606,347**
Goliath	**715.00**	**EA**	*326.27* **233,282**	*99.24* **70,955**	*1,108.80* **792,792**	*1,534.31* **1,097,030**	*1,534.31* **1,097,030**
EFH-8	**715.00**	**EA**	*149.52* **106,906**	*54.44* **38,926**	*504.00* **360,360**	*707.96* **506,192**	*707.96* **506,192**
USR Goliath Reef Ball-Material	715.00	EA	*0.00* 0	*0.00* 0	*504.00* 360,360	*504.00* 360,360	*504.00* 360,360
USR LdLg Load Large Balls onto Truck @ Plant	715.00	EA	*6.82* 4,878	*4.64* 3,318	*0.00* 0	*11.46* 8,196	*11.46* 8,196
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	715.00	EA	*9.29* 6,646	*13.08* 9,351	*0.00* 0	*22.37* 15,997	*22.37* 15,997
USR StkLg Unload Large Balls & Stockpile	715.00	EA	*6.82* 4,878	*4.64* 3,318	*0.00* 0	*11.46* 8,196	*11.46* 8,196
USR BrgBy8 Load Large Balls into Barge EFH-8	715.00	EA	*53.41* 38,185	*15.40* 11,013	*0.00* 0	*68.81* 49,198	*68.81* 49,198
USR PlcBy8 Transport Large Balls by Barge & Place- Site EFH-8	715.00	EA	*73.18* 52,321	*16.68* 11,925	*0.00* 0	*89.85* 64,246	*89.85* 64,246

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Marine Mattress Mats	**715.00**	**EA**	*176.75* **126,376**	*44.80* **32,030**	*604.80* **432,432**	*826.35* **590,838**	*826.35* **590,838**
USR MMMk Load Gabion onto Barge	715.00	EA	*74.57* 53,319	*21.51* 15,378	*0.00* 0	*96.08* 68,697	*96.08* 68,697
USR MMPlc Transport & Place in Water	715.00	EA	*102.18* 73,057	*23.29* 16,651	*0.00* 0	*125.47* 89,709	*125.47* 89,709
USR Marine Mattress 8'x8'x12"- material	715.00	EA	*0.00* 0	*0.00* 0	*604.80* 432,432	*604.80* 432,432	*604.80* 432,432
Super	**715.00**	**EA**	*326.27* **233,282**	*99.24* **70,955**	*1,056.30* **755,255**	*1,481.81* **1,059,492**	*1,481.81* **1,059,492**
EFH-8	**715.00**	**EA**	*149.52* **106,906**	*54.44* **38,926**	*451.50* **322,823**	*655.46* **468,654**	*655.46* **468,654**
USR Super Ball-Material	715.00	EA	*0.00* 0	*0.00* 0	*451.50* 322,823	*451.50* 322,823	*451.50* 322,823
USR LdLg Load Large Balls onto Truck @ Plant	715.00	EA	*6.82* 4,878	*4.64* 3,318	*0.00* 0	*11.46* 8,196	*11.46* 8,196
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	715.00	EA	*9.29* 6,646	*13.08* 9,351	*0.00* 0	*22.37* 15,997	*22.37* 15,997
USR StkLg Unload Large Balls & Stockpile	715.00	EA	*6.82* 4,878	*4.64* 3,318	*0.00* 0	*11.46* 8,196	*11.46* 8,196
USR BrgBy8 Load Large Balls into Barge RH-8	715.00	EA	*53.41* 38,185	*15.40* 11,013	*0.00* 0	*68.81* 49,198	*68.81* 49,198
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	715.00	EA	*73.18* 52,321	*16.68* 11,925	*0.00* 0	*89.85* 64,246	*89.85* 64,246
Marine Mattress Mats	**715.00**	**EA**	*176.75* **126,376**	*44.80* **32,030**	*604.80* **432,432**	*826.35* **590,838**	*826.35* **590,838**
USR MMMk Load Gabion onto Barge	715.00	EA	*74.57* 53,319	*21.51* 15,378	*0.00* 0	*96.08* 68,697	*96.08* 68,697
USR MMPlc Transport & Place in Water	715.00	EA	*102.18* 73,057	*23.29* 16,651	*0.00* 0	*125.47* 89,709	*125.47* 89,709
USR Marine Mattress 8'x8'x12"- material	715.00	EA	*0.00* 0	*0.00* 0	*604.80* 432,432	*604.80* 432,432	*604.80* 432,432
Ultra	**358.00**	**EA**	*257.68* **92,249**	*81.85* **29,304**	*916.96* **328,272**	*1,256.49* **449,825**	*1,256.49* **449,825**
			149.52	*54.44*	*388.50*	*592.46*	*592.46*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
EFH-8	**358.00**	**EA**	**53,528**	**19,490**	**139,083**	**212,101**	**212,101**
USR Ultra Reef Ball-Material	358.00	EA	*0.00* 0	*0.00* 0	*388.50* 139,083	*388.50* 139,083	*388.50* 139,083
USR LdLg Load Large Balls onto Truck @ Plant	358.00	EA	*6.82* 2,442	*4.64* 1,661	*0.00* 0	*11.46* 4,104	*11.46* 4,104
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	358.00	EA	*9.29* 3,327	*13.08* 4,682	*0.00* 0	*22.37* 8,010	*22.37* 8,010
USR StkLg Unload Large Balls & Stockpile	358.00	EA	*6.82* 2,442	*4.64* 1,661	*0.00* 0	*11.46* 4,104	*11.46* 4,104
USR BrgBy8 Load Large Balls into Barge RH-8	358.00	EA	*53.41* 19,119	*15.40* 5,514	*0.00* 0	*68.81* 24,633	*68.81* 24,633
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	358.00	EA	*73.18* 26,197	*16.68* 5,971	*0.00* 0	*89.85* 32,168	*89.85* 32,168
Marine Mattress Mats	**358.00**	**EA**	*108.16* **38,721**	*27.41* **9,814**	*528.46* **189,189**	*664.03* **237,724**	*664.03* **237,724**
USR MMMk6 Load Gabion onto Barge 6'x6'	358.00	EA	*45.63* 16,337	*13.16* 4,712	*0.00* 0	*58.80* 21,049	*58.80* 21,049
USR MMPlc6 Transport & Place in Water 6'x6'	358.00	EA	*62.53* 22,385	*14.25* 5,102	*0.00* 0	*76.78* 27,487	*76.78* 27,487
USR Marine Mattress 6'x6' x6"- material	715.00	EA	*0.00* 0	*0.00* 0	*264.60* 189,189	*264.60* 189,189	*264.60* 189,189
EFH Adaptive Management	**1.00**	**EA**	*433,149.94* **433,150**	*75,381.15* **75,381**	*0.00* **0**	*508,531.08* **508,531**	*508,531.08* **508,531**
Clean Reef Balls	**1.00**	**EA**	*19,533.33* **19,533**	*1,613.10* **1,613**	*0.00* **0**	*21,146.44* **21,146**	*21,146.44* **21,146**
USR Clean Bay Balls	175.00	EA	*53.89* 9,430	*4.45* 779	*0.00* 0	*58.33* 10,209	*58.33* 10,209
USR Clean Large Reef Balls	75.00	EA	*134.71* 10,103	*11.12* 834	*0.00* 0	*145.84* 10,938	*145.84* 10,938
Relocate Reef Balls	**1.00**	**EA**	*413,616.60* **413,617**	*73,768.04* **73,768**	*0.00* **0**	*487,384.65* **487,385**	*487,384.65* **487,385**
USR RelBy Relocate Bay Ball by Barge	1,100.00	EA	*200.50* 220,546	*35.76* 39,334	*0.00* 0	*236.25* 259,880	*236.25* 259,880
USR RelLg Relocate Large Balls by Barge	500.00	EA	*386.14* 193,071	*68.87* 34,434	*0.00* 0	*455.01* 227,505	*455.01* 227,505

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			1,618,372.84	*476,186.50*	*3,317,797.00*	*5,412,356.34*	*5,412,356.34*
Reef Habitat Construction -Phase 2	**1.00**	**EA**	**1,618,373**	**476,187**	**3,317,797**	**5,412,356**	**5,412,356**
			52.94	*18.99*	*94.50*	*166.44*	*166.44*
EFH Bay Balls	**7,046.00**	**EA**	**373,044**	**133,832**	**665,847**	**1,172,722**	**1,172,722**
			52.03	*18.76*	*94.50*	*165.29*	*165.29*
Bay Ball EFH-1	**809.00**	**EA**	**42,088**	**15,178**	**76,451**	**133,717**	**133,717**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	809.00	EA	0	0	76,451	76,451	76,451
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	809.00	EA	2,208	1,502	0	3,709	3,709
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	809.00	EA	2,276	3,203	0	5,479	5,479
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	809.00	EA	2,208	1,502	0	3,709	3,709
			18.46	*5.32*	*0.00*	*23.78*	*23.78*
USR BrgBy1 Load Bay Balls into Barge EFH-1	809.00	EA	14,934	4,307	0	19,242	19,242
			25.29	*5.77*	*0.00*	*31.06*	*31.06*
USR PlcBy1 Transport Bay Ball by Barge & Place- Site RH-1	809.00	EA	20,463	4,664	0	25,127	25,127
			52.36	*18.85*	*94.50*	*165.70*	*165.70*
Bay Ball EFH-2	**4,577.00**	**EA**	**239,642**	**86,255**	**432,527**	**758,424**	**758,424**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	4,577.00	EA	0	0	432,527	432,527	432,527
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	4,577.00	EA	12,489	8,496	0	20,985	20,985
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	4,577.00	EA	12,878	18,121	0	31,000	31,000
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	4,577.00	EA	12,489	8,496	0	20,985	20,985
			18.60	*5.36*	*0.00*	*23.97*	*23.97*
USR BrgBy2 Load Bay Balls into Barge EFH-2	4,577.00	EA	85,134	24,555	0	109,689	109,689
			25.49	*5.81*	*0.00*	*31.30*	*31.30*
USR PlcBy2 Transport Bay Ball by Barge & Place- Site RH-2	4,577.00	EA	116,651	26,587	0	143,238	143,238
			54.50	*19.39*	*94.50*	*168.39*	*168.39*
Bay Ball EFH-3	**643.00**	**EA**	**35,045**	**12,467**	**60,764**	**108,276**	**108,276**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR Bay Ball-Material	643.00	EA	0	0	60,764	60,764	60,764
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	643.00	EA	1,755	1,194	0	2,948	2,948
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	643.00	EA	1,809	2,546	0	4,355	4,355
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	643.00	EA	1,755	1,194	0	2,948	2,948
			19.51	*5.63*	*0.00*	*25.13*	*25.13*
USR BrgBy3 Load Bay Balls into Barge EFH-3	643.00	EA	12,542	3,617	0	16,159	16,159
			26.73	*6.09*	*0.00*	*32.82*	*32.82*
USR PlcBy3 Transport Bay Ball by Barge & Place- Site RH-3	643.00	EA	17,185	3,917	0	21,102	21,102
			55.33	*19.60*	*94.50*	*169.43*	*169.43*
Bay Ball EFH-4	**1,017.00**	**EA**	**56,269**	**19,931**	**96,107**	**172,306**	**172,306**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	1,017.00	EA	0	0	96,107	96,107	96,107
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	1,017.00	EA	2,775	1,888	0	4,663	4,663
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	1,017.00	EA	2,862	4,027	0	6,888	6,888
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	1,017.00	EA	2,775	1,888	0	4,663	4,663
			19.85	*5.73*	*0.00*	*25.58*	*25.58*
USR BrgBy4 Load Bay Balls into Barge EFH-4	1,017.00	EA	20,191	5,824	0	26,015	26,015
			27.20	*6.20*	*0.00*	*33.40*	*33.40*
USR PlcBy4 Transport Bay Ball by Barge & Place- Site RH-4	1,017.00	EA	27,666	6,306	0	33,971	33,971
			50.06	*18.92*	*153.26*	*222.24*	*222.24*
EFH Large Balls Normal Foundation	**5,061.00**	**EA**	**253,365**	**95,759**	**775,632**	**1,124,756**	**1,124,756**
			156.23	*61.58*	*505.04*	*722.85*	*722.85*
Goliath	**674.00**	**EA**	**105,298**	**41,504**	**340,396**	**487,198**	**487,198**
			160.11	*66.52*	*505.79*	*732.42*	*732.42*
EFH-5, 6, & 7	**390.00**	**EA**	**62,441**	**25,942**	**197,260**	**285,644**	**285,644**
			6,586.79	*5,333.28*	*700.00*	*12,620.07*	*12,620.07*
Mob	**1.00**	**EA**	**6,587**	**5,333**	**700**	**12,620**	**12,620**
			6,586.79	*5,333.28*	*700.00*	*12,620.07*	*12,620.07*
Mob Marine equipment and Cranes	**1.00**	**EA**	**6,587**	**5,333**	**700**	**12,620**	**12,620**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			411.67	*333.33*	*0.00*	*745.00*	*745.00*
USR WtrMb Mob Marine Equipment & Cranes	16.00	HR	6,587	5,333	0	11,920	11,920
USR Misc Mob work	1.00	LS	0	0	700	700	700
			143.22	*52.84*	*504.00*	*700.06*	*700.06*
Load & Place Reef Balls	**390.00**	**EA**	**55,854**	**20,609**	**196,560**	**273,023**	**273,023**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	390.00	EA	0	0	196,560	196,560	196,560
			50.75	*14.64*	*0.00*	*65.38*	*65.38*
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	390.00	EA	19,791	5,708	0	25,499	25,499
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	390.00	EA	2,661	1,810	0	4,470	4,470
			69.53	*15.85*	*0.00*	*85.38*	*85.38*
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	390.00	EA	27,117	6,181	0	33,298	33,298
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	390.00	EA	2,661	1,810	0	4,470	4,470
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	390.00	EA	3,625	5,101	0	8,725	8,725
			149.52	*54.44*	*504.00*	*707.96*	*707.96*
EFH-8	**238.00**	**EA**	**35,586**	**12,957**	**119,952**	**168,495**	**168,495**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	238.00	EA	0	0	119,952	119,952	119,952
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	238.00	EA	1,624	1,104	0	2,728	2,728
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	238.00	EA	2,212	3,113	0	5,325	5,325
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	238.00	EA	1,624	1,104	0	2,728	2,728
			53.41	*15.40*	*0.00*	*68.81*	*68.81*
USR BrgBy8 Load Large Balls into Barge RH-8	238.00	EA	12,710	3,666	0	16,376	16,376
			73.18	*16.68*	*0.00*	*89.85*	*89.85*
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	238.00	EA	17,416	3,969	0	21,385	21,385
			158.08	*56.61*	*504.00*	*718.69*	*718.69*
EFH-9	**46.00**	**EA**	**7,271**	**2,604**	**23,184**	**33,060**	**33,060**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR Goliath Reef Ball-Material	46.00	EA	0	0	23,184	23,184	23,184
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	314	213	0	527	527
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	428	602	0	1,029	1,029
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	46.00	EA	314	213	0	527	527
			57.02	*16.44*	*0.00*	*73.46*	*73.46*
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	2,623	756	0	3,379	3,379
			78.12	*17.81*	*0.00*	*95.93*	*95.93*
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	3,594	819	0	4,413	4,413
			146.46	*53.67*	*451.50*	*651.62*	*651.62*
Super	**674.00**	**EA**	**98,711**	**36,170**	**304,311**	**439,193**	**439,193**
			143.22	*52.84*	*451.50*	*647.56*	*647.56*
EFH-5, 6, & 7	**390.00**	**EA**	**55,854**	**20,609**	**176,085**	**252,548**	**252,548**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	390.00	EA	0	0	176,085	176,085	176,085
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	390.00	EA	2,661	1,810	0	4,470	4,470
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	390.00	EA	3,625	5,101	0	8,725	8,725
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	390.00	EA	2,661	1,810	0	4,470	4,470
			50.75	*14.64*	*0.00*	*65.38*	*65.38*
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	390.00	EA	19,791	5,708	0	25,499	25,499
			69.53	*15.85*	*0.00*	*85.38*	*85.38*
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	390.00	EA	27,117	6,181	0	33,298	33,298
			149.52	*54.44*	*451.50*	*655.46*	*655.46*
EFH-8	**238.00**	**EA**	**35,586**	**12,957**	**107,457**	**156,000**	**156,000**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	238.00	EA	0	0	107,457	107,457	107,457
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	238.00	EA	1,624	1,104	0	2,728	2,728
			9.29	*13.08*	*0.00*	*22.37*	*22.37*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	238.00	EA	2,212	3,113	0	5,325	5,325
USR StkLg Unload Large Balls & Stockpile	238.00	EA	*6.82* 1,624	*4.64* 1,104	*0.00* 0	*11.46* 2,728	*11.46* 2,728
USR BrgBy8 Load Large Balls into Barge RH-8	238.00	EA	*53.41* 12,710	*15.40* 3,666	*0.00* 0	*68.81* 16,376	*68.81* 16,376
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	238.00	EA	*73.18* 17,416	*16.68* 3,969	*0.00* 0	*89.85* 21,385	*89.85* 21,385
EFH-9	**46.00**	**EA**	*158.08* **7,271**	*56.61* **2,604**	*451.50* **20,769**	*666.19* **30,645**	*666.19* **30,645**
USR Super Ball-Material	46.00	EA	*0.00* 0	*0.00* 0	*451.50* 20,769	*451.50* 20,769	*451.50* 20,769
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	*9.29* 428	*13.08* 602	*0.00* 0	*22.37* 1,029	*22.37* 1,029
USR StkLg Unload Large Balls & Stockpile	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	*57.02* 2,623	*16.44* 756	*0.00* 0	*73.46* 3,379	*73.46* 3,379
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	*78.12* 3,594	*17.81* 819	*0.00* 0	*95.93* 4,413	*95.93* 4,413
Ultra	**337.00**	**EA**	*146.46* **49,356**	*53.67* **18,085**	*388.50* **130,925**	*588.62* **198,365**	*588.62* **198,365**
EFH-5, 6, & 7	**195.00**	**EA**	*143.22* **27,927**	*52.84* **10,305**	*388.50* **75,758**	*584.56* **113,989**	*584.56* **113,989**
USR Ultra Reef Ball-Material	195.00	EA	*0.00* 0	*0.00* 0	*388.50* 75,758	*388.50* 75,758	*388.50* 75,758
USR LdLg Load Large Balls onto Truck @ Plant	195.00	EA	*6.82* 1,330	*4.64* 905	*0.00* 0	*11.46* 2,235	*11.46* 2,235
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	195.00	EA	*9.29* 1,812	*13.08* 2,550	*0.00* 0	*22.37* 4,363	*22.37* 4,363
USR StkLg Unload Large Balls & Stockpile	195.00	EA	*6.82* 1,330	*4.64* 905	*0.00* 0	*11.46* 2,235	*11.46* 2,235
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	195.00	EA	*50.75* 9,895	*14.64* 2,854	*0.00* 0	*65.38* 12,750	*65.38* 12,750

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	195.00	EA	*69.53* 13,559	*15.85* 3,090	*0.00* 0	*85.38* 16,649	*85.38* 16,649
EFH-8	**119.00**	**EA**	*149.52* **17,793**	*54.44* **6,479**	*388.50* **46,232**	*592.46* **70,503**	*592.46* **70,503**
USR Ultra Reef Ball-Material	119.00	EA	*0.00* 0	*0.00* 0	*388.50* 46,232	*388.50* 46,232	*388.50* 46,232
USR LdLg Load Large Balls onto Truck @ Plant	119.00	EA	*6.82* 812	*4.64* 552	*0.00* 0	*11.46* 1,364	*11.46* 1,364
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	119.00	EA	*9.29* 1,106	*13.08* 1,556	*0.00* 0	*22.37* 2,662	*22.37* 2,662
USR StkLg Unload Large Balls & Stockpile	119.00	EA	*6.82* 812	*4.64* 552	*0.00* 0	*11.46* 1,364	*11.46* 1,364
USR BrgBy8 Load Large Balls into Barge RH-8	119.00	EA	*53.41* 6,355	*15.40* 1,833	*0.00* 0	*68.81* 8,188	*68.81* 8,188
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	119.00	EA	*73.18* 8,708	*16.68* 1,985	*0.00* 0	*89.85* 10,693	*89.85* 10,693
EFH-9	**23.00**	**EA**	*158.08* **3,636**	*56.61* **1,302**	*388.50* **8,936**	*603.19* **13,873**	*603.19* **13,873**
USR Ultra Reef Ball-Material	23.00	EA	*0.00* 0	*0.00* 0	*388.50* 8,936	*388.50* 8,936	*388.50* 8,936
USR LdLg Load Large Balls onto Truck @ Plant	23.00	EA	*6.82* 157	*4.64* 107	*0.00* 0	*11.46* 264	*11.46* 264
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	23.00	EA	*9.29* 214	*13.08* 301	*0.00* 0	*22.37* 515	*22.37* 515
USR StkLg Unload Large Balls & Stockpile	23.00	EA	*6.82* 157	*4.64* 107	*0.00* 0	*11.46* 264	*11.46* 264
USR BrgBy9 Load Large Balls into Barge RH-9	23.00	EA	*57.02* 1,311	*16.44* 378	*0.00* 0	*73.46* 1,690	*73.46* 1,690
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	23.00	EA	*78.12* 1,797	*17.81* 410	*0.00* 0	*95.93* 2,206	*95.93* 2,206
EFH Large Balls Soft Foundation	**1,788.00**	**EA**	*312.54* **558,814**	*95.76* **171,215**	*1,049.40* **1,876,319**	*1,457.69* **2,606,347**	*1,457.69* **2,606,347**
Goliath	**715.00**	**EA**	*326.27* **233,282**	*99.24* **70,955**	*1,108.80* **792,792**	*1,534.31* **1,097,030**	*1,534.31* **1,097,030**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			149.52	*54.44*	*504.00*	*707.96*	*707.96*
EFH-8	**715.00**	**EA**	**106,906**	**38,926**	**360,360**	**506,192**	**506,192**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	715.00	EA	0	0	360,360	360,360	360,360
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	715.00	EA	4,878	3,318	0	8,196	8,196
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	715.00	EA	6,646	9,351	0	15,997	15,997
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	715.00	EA	4,878	3,318	0	8,196	8,196
			53.41	*15.40*	*0.00*	*68.81*	*68.81*
USR BrgBy8 Load Large Balls into Barge EFH-8	715.00	EA	38,185	11,013	0	49,198	49,198
			73.18	*16.68*	*0.00*	*89.85*	*89.85*
USR PlcBy8 Transport Large Balls by Barge & Place- Site EFH-8	715.00	EA	52,321	11,925	0	64,246	64,246
			176.75	*44.80*	*604.80*	*826.35*	*826.35*
Marine Mattress Mats	**715.00**	**EA**	**126,376**	**32,030**	**432,432**	**590,838**	**590,838**
			74.57	*21.51*	*0.00*	*96.08*	*96.08*
USR MMMk Load Gabion onto Barge	715.00	EA	53,319	15,378	0	68,697	68,697
			102.18	*23.29*	*0.00*	*125.47*	*125.47*
USR MMPlc Transport & Place in Water	715.00	EA	73,057	16,651	0	89,709	89,709
			0.00	*0.00*	*604.80*	*604.80*	*604.80*
USR Marine Mattress 8'x8'x12"- material	715.00	EA	0	0	432,432	432,432	432,432
			326.27	*99.24*	*1,056.30*	*1,481.81*	*1,481.81*
Super	**715.00**	**EA**	**233,282**	**70,955**	**755,255**	**1,059,492**	**1,059,492**
			149.52	*54.44*	*451.50*	*655.46*	*655.46*
EFH-8	**715.00**	**EA**	**106,906**	**38,926**	**322,823**	**468,654**	**468,654**
			0.00	*0.00*	*451.50*	*451.50*	*451.50*
USR Super Ball-Material	715.00	EA	0	0	322,823	322,823	322,823
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	715.00	EA	4,878	3,318	0	8,196	8,196
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	715.00	EA	6,646	9,351	0	15,997	15,997
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	715.00	EA	4,878	3,318	0	8,196	8,196
			53.41	*15.40*	*0.00*	*68.81*	*68.81*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR BrgBy8 Load Large Balls into Barge RH-8	715.00	EA	38,185	11,013	0	49,198	49,198
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	715.00	EA	*73.18* 52,321	*16.68* 11,925	*0.00* 0	*89.85* 64,246	*89.85* 64,246
Marine Mattress Mats	**715.00**	**EA**	*176.75* **126,376**	*44.80* **32,030**	*604.80* **432,432**	*826.35* **590,838**	*826.35* **590,838**
USR MMMk Load Gabion onto Barge	715.00	EA	*74.57* 53,319	*21.51* 15,378	*0.00* 0	*96.08* 68,697	*96.08* 68,697
USR MMPlc Transport & Place in Water	715.00	EA	*102.18* 73,057	*23.29* 16,651	*0.00* 0	*125.47* 89,709	*125.47* 89,709
USR Marine Mattress 8'x8'x12"- material	715.00	EA	*0.00* 0	*0.00* 0	*604.80* 432,432	*604.80* 432,432	*604.80* 432,432
Ultra	**358.00**	**EA**	*257.68* **92,249**	*81.85* **29,304**	*916.96* **328,272**	*1,256.49* **449,825**	*1,256.49* **449,825**
EFH-8	**358.00**	**EA**	*149.52* **53,528**	*54.44* **19,490**	*388.50* **139,083**	*592.46* **212,101**	*592.46* **212,101**
USR Ultra Reef Ball-Material	358.00	EA	*0.00* 0	*0.00* 0	*388.50* 139,083	*388.50* 139,083	*388.50* 139,083
USR LdLg Load Large Balls onto Truck @ Plant	358.00	EA	*6.82* 2,442	*4.64* 1,661	*0.00* 0	*11.46* 4,104	*11.46* 4,104
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	358.00	EA	*9.29* 3,327	*13.08* 4,682	*0.00* 0	*22.37* 8,010	*22.37* 8,010
USR StkLg Unload Large Balls & Stockpile	358.00	EA	*6.82* 2,442	*4.64* 1,661	*0.00* 0	*11.46* 4,104	*11.46* 4,104
USR BrgBy8 Load Large Balls into Barge RH-8	358.00	EA	*53.41* 19,119	*15.40* 5,514	*0.00* 0	*68.81* 24,633	*68.81* 24,633
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	358.00	EA	*73.18* 26,197	*16.68* 5,971	*0.00* 0	*89.85* 32,168	*89.85* 32,168
Marine Mattress Mats	**358.00**	**EA**	*108.16* **38,721**	*27.41* **9,814**	*528.46* **189,189**	*664.03* **237,724**	*664.03* **237,724**
USR MMMk6 Load Gabion onto Barge 6'x6'	358.00	EA	*45.63* 16,337	*13.16* 4,712	*0.00* 0	*58.80* 21,049	*58.80* 21,049
USR MMPlc6 Transport & Place in Water 6'x6'	358.00	EA	*62.53* 22,385	*14.25* 5,102	*0.00* 0	*76.78* 27,487	*76.78* 27,487
USR Marine Mattress 6'x6' x6"- material	715.00	EA	*0.00* 0	*0.00* 0	*264.60* 189,189	*264.60* 189,189	*264.60* 189,189

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			433,149.94	*75,381.15*	*0.00*	*508,531.08*	*508,531.08*
EFH Adaptive Management	**1.00**	**EA**	**433,150**	**75,381**	**0**	**508,531**	**508,531**
			19,533.33	*1,613.10*	*0.00*	*21,146.44*	*21,146.44*
Clean Reef Balls	**1.00**	**EA**	**19,533**	**1,613**	**0**	**21,146**	**21,146**
			53.89	*4.45*	*0.00*	*58.33*	*58.33*
USR Clean Bay Balls	175.00	EA	9,430	779	0	10,209	10,209
			134.71	*11.12*	*0.00*	*145.84*	*145.84*
USR Clean Large Reef Balls	75.00	EA	10,103	834	0	10,938	10,938
			413,616.60	*73,768.04*	*0.00*	*487,384.65*	*487,384.65*
Relocate Reef Balls	**1.00**	**EA**	**413,617**	**73,768**	**0**	**487,385**	**487,385**
			200.50	*35.76*	*0.00*	*236.25*	*236.25*
USR RelBy Relocate Bay Ball by Barge	1,100.00	EA	220,546	39,334	0	259,880	259,880
			386.14	*68.87*	*0.00*	*455.01*	*455.01*
USR RelLg Relocate Large Balls by Barge	500.00	EA	193,071	34,434	0	227,505	227,505
			1,186,385.81	*401,204.76*	*3,322,337.20*	*4,909,927.77*	*4,909,927.77*
Reef Habitat Construction -Phase 3	**1.00**	**EA**	**1,186,386**	**401,205**	**3,322,337**	**4,909,928**	**4,909,928**
			52.94	*18.99*	*94.50*	*166.44*	*166.44*
EFH Bay Balls	**7,044.00**	**EA**	**372,934**	**133,792**	**665,658**	**1,172,384**	**1,172,384**
			52.03	*18.76*	*94.50*	*165.29*	*165.29*
Bay Ball EFH-1	**810.00**	**EA**	**42,140**	**15,196**	**76,545**	**133,882**	**133,882**
			0.00	*0.00*	*94.50*	*94.50*	*94.50*
USR Bay Ball-Material	810.00	EA	0	0	76,545	76,545	76,545
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR StkBy Unload Bay Balls & Stockpile	810.00	EA	2,210	1,504	0	3,714	3,714
			2.81	*3.96*	*0.00*	*6.77*	*6.77*
USR TkBy Transport Bay Balls-Truck	810.00	EA	2,279	3,207	0	5,486	5,486
			2.73	*1.86*	*0.00*	*4.58*	*4.58*
USR LdBy Load Bay Balls onto Truck @ Plant	810.00	EA	2,210	1,504	0	3,714	3,714
			18.46	*5.32*	*0.00*	*23.78*	*23.78*
USR BrgBy1 Load Bay Balls into Barge EFH-1	810.00	EA	14,953	4,313	0	19,265	19,265
			25.29	*5.77*	*0.00*	*31.06*	*31.06*
USR PlcBy1 Transport Bay Ball by Barge & Place- Site RH-1	810.00	EA	20,488	4,670	0	25,158	25,158
			52.36	*18.85*	*94.50*	*165.70*	*165.70*
Bay Ball EFH-2	**4,576.00**	**EA**	**239,590**	**86,237**	**432,432**	**758,258**	**758,258**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR Bay Ball-Material	4,576.00	EA	*0.00* 0	*0.00* 0	*94.50* 432,432	*94.50* 432,432	*94.50* 432,432
USR StkBy Unload Bay Balls & Stockpile	4,576.00	EA	*2.73* 12,487	*1.86* 8,494	*0.00* 0	*4.58* 20,981	*4.58* 20,981
USR TkBy Transport Bay Balls-Truck	4,576.00	EA	*2.81* 12,875	*3.96* 18,117	*0.00* 0	*6.77* 30,993	*6.77* 30,993
USR LdBy Load Bay Balls onto Truck @ Plant	4,576.00	EA	*2.73* 12,487	*1.86* 8,494	*0.00* 0	*4.58* 20,981	*4.58* 20,981
USR BrgBy2 Load Bay Balls into Barge EFH-2	4,576.00	EA	*18.60* 85,116	*5.36* 24,549	*0.00* 0	*23.97* 109,665	*23.97* 109,665
USR PlcBy2 Transport Bay Ball by Barge & Place- Site RH-2	4,576.00	EA	*25.49* 116,625	*5.81* 26,581	*0.00* 0	*31.30* 143,207	*31.30* 143,207
Bay Ball EFH-3	**642.00**	**EA**	*54.50* **34,991**	*19.39* **12,448**	*94.50* **60,669**	*168.39* **108,107**	*168.39* **108,107**
USR Bay Ball-Material	642.00	EA	*0.00* 0	*0.00* 0	*94.50* 60,669	*94.50* 60,669	*94.50* 60,669
USR StkBy Unload Bay Balls & Stockpile	642.00	EA	*2.73* 1,752	*1.86* 1,192	*0.00* 0	*4.58* 2,944	*4.58* 2,944
USR TkBy Transport Bay Balls-Truck	642.00	EA	*2.81* 1,806	*3.96* 2,542	*0.00* 0	*6.77* 4,348	*6.77* 4,348
USR LdBy Load Bay Balls onto Truck @ Plant	642.00	EA	*2.73* 1,752	*1.86* 1,192	*0.00* 0	*4.58* 2,944	*4.58* 2,944
USR BrgBy3 Load Bay Balls into Barge EFH-3	642.00	EA	*19.51* 12,522	*5.63* 3,612	*0.00* 0	*25.13* 16,134	*25.13* 16,134
USR PlcBy3 Transport Bay Ball by Barge & Place- Site RH-3	642.00	EA	*26.73* 17,158	*6.09* 3,911	*0.00* 0	*32.82* 21,069	*32.82* 21,069
Bay Ball EFH-4	**1,016.00**	**EA**	*55.33* **56,213**	*19.60* **19,912**	*94.50* **96,012**	*169.43* **172,137**	*169.43* **172,137**
USR Bay Ball-Material	1,016.00	EA	*0.00* 0	*0.00* 0	*94.50* 96,012	*94.50* 96,012	*94.50* 96,012
USR StkBy Unload Bay Balls & Stockpile	1,016.00	EA	*2.73* 2,772	*1.86* 1,886	*0.00* 0	*4.58* 4,658	*4.58* 4,658
USR TkBy Transport Bay Balls-Truck	1,016.00	EA	*2.81* 2,859	*3.96* 4,023	*0.00* 0	*6.77* 6,881	*6.77* 6,881
USR LdBy Load Bay Balls onto Truck @ Plant	1,016.00	EA	*2.73* 2,772	*1.86* 1,886	*0.00* 0	*4.58* 4,658	*4.58* 4,658

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR BrgBy4 Load Bay Balls into Barge EFH-4	1,016.00	EA	*19.85* 20,171	*5.73* 5,818	*0.00* 0	*25.58* 25,989	*25.58* 25,989
USR PlcBy4 Transport Bay Ball by Barge & Place- Site RH-4	1,016.00	EA	*27.20* 27,639	*6.20* 6,299	*0.00* 0	*33.40* 33,938	*33.40* 33,938
EFH Large Balls Normal Foundation	**5,061.00**	**EA**	*50.24* **254,243**	*18.98* **96,081**	*153.79* **778,320**	*223.01* **1,128,644**	*223.01* **1,128,644**
Goliath	**676.00**	**EA**	*156.20* **105,591**	*61.55* **41,611**	*505.04* **341,404**	*722.79* **488,606**	*722.79* **488,606**
EFH-5, 6, & 7	**391.00**	**EA**	*160.06* **62,584**	*66.48* **25,995**	*505.79* **197,764**	*732.34* **286,344**	*732.34* **286,344**
Mob	**1.00**	**EA**	*6,586.79* **6,587**	*5,333.28* **5,333**	*700.00* **700**	*12,620.07* **12,620**	*12,620.07* **12,620**
Mob Marine equipment and Cranes	**1.00**	**EA**	*6,586.79* **6,587**	*5,333.28* **5,333**	*700.00* **700**	*12,620.07* **12,620**	*12,620.07* **12,620**
USR WtrMb Mob Marine Equipment & Cranes	16.00	HR	*411.67* 6,587	*333.33* 5,333	*0.00* 0	*745.00* 11,920	*745.00* 11,920
USR Misc Mob work	1.00	LS	0	0	700	700	700
Load & Place Reef Balls	**390.00**	**EA**	*143.58* **55,998**	*52.98* **20,662**	*505.29* **197,064**	*701.86* **273,724**	*701.86* **273,724**
USR Goliath Reef Ball-Material	391.00	EA	*0.00* 0	*0.00* 0	*504.00* 197,064	*504.00* 197,064	*504.00* 197,064
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	391.00	EA	*50.75* 19,842	*14.64* 5,723	*0.00* 0	*65.38* 25,565	*65.38* 25,565
USR LdLg Load Large Balls onto Truck @ Plant	391.00	EA	*6.82* 2,667	*4.64* 1,814	*0.00* 0	*11.46* 4,482	*11.46* 4,482
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	391.00	EA	*69.53* 27,187	*15.85* 6,197	*0.00* 0	*85.38* 33,384	*85.38* 33,384
USR StkLg Unload Large Balls & Stockpile	391.00	EA	*6.82* 2,667	*4.64* 1,814	*0.00* 0	*11.46* 4,482	*11.46* 4,482
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	391.00	EA	*9.29* 3,634	*13.08* 5,114	*0.00* 0	*22.37* 8,748	*22.37* 8,748
EFH-8	**239.00**	**EA**	*149.52* **35,735**	*54.44* **13,011**	*504.00* **120,456**	*707.96* **169,203**	*707.96* **169,203**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR Goliath Reef Ball-Material	239.00	EA	*0.00* 0	*0.00* 0	*504.00* 120,456	*504.00* 120,456	*504.00* 120,456
USR LdLg Load Large Balls onto Truck @ Plant	239.00	EA	*6.82* 1,630	*4.64* 1,109	*0.00* 0	*11.46* 2,740	*11.46* 2,740
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	239.00	EA	*9.29* 2,221	*13.08* 3,126	*0.00* 0	*22.37* 5,347	*22.37* 5,347
USR StkLg Unload Large Balls & Stockpile	239.00	EA	*6.82* 1,630	*4.64* 1,109	*0.00* 0	*11.46* 2,740	*11.46* 2,740
USR BrgBy8 Load Large Balls into Barge RH-8	239.00	EA	*53.41* 12,764	*15.40* 3,681	*0.00* 0	*68.81* 16,445	*68.81* 16,445
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	239.00	EA	*73.18* 17,489	*16.68* 3,986	*0.00* 0	*89.85* 21,475	*89.85* 21,475
EFH-9	**46.00**	**EA**	*158.08* **7,271**	*56.61* **2,604**	*504.00* **23,184**	*718.69* **33,060**	*718.69* **33,060**
USR Goliath Reef Ball-Material	46.00	EA	*0.00* 0	*0.00* 0	*504.00* 23,184	*504.00* 23,184	*504.00* 23,184
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	*9.29* 428	*13.08* 602	*0.00* 0	*22.37* 1,029	*22.37* 1,029
USR StkLg Unload Large Balls & Stockpile	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	*57.02* 2,623	*16.44* 756	*0.00* 0	*73.46* 3,379	*73.46* 3,379
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	*78.12* 3,594	*17.81* 819	*0.00* 0	*95.93* 4,413	*95.93* 4,413
Super	**674.00**	**EA**	*146.89* **99,004**	*53.82* **36,278**	*452.84* **305,214**	*653.55* **440,496**	*653.55* **440,496**
EFH-5, 6, & 7	**391.00**	**EA**	*143.22* **55,998**	*52.84* **20,662**	*451.50* **176,537**	*647.56* **253,196**	*647.56* **253,196**
USR Super Ball-Material	391.00	EA	*0.00* 0	*0.00* 0	*451.50* 176,537	*451.50* 176,537	*451.50* 176,537
USR LdLg Load Large Balls onto Truck @ Plant	391.00	EA	*6.82* 2,667	*4.64* 1,814	*0.00* 0	*11.46* 4,482	*11.46* 4,482
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	391.00	EA	*9.29* 3,634	*13.08* 5,114	*0.00* 0	*22.37* 8,748	*22.37* 8,748

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR StkLg Unload Large Balls & Stockpile	391.00	EA	*6.82* 2,667	*4.64* 1,814	*0.00* 0	*11.46* 4,482	*11.46* 4,482
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	391.00	EA	*50.75* 19,842	*14.64* 5,723	*0.00* 0	*65.38* 25,565	*65.38* 25,565
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	391.00	EA	*69.53* 27,187	*15.85* 6,197	*0.00* 0	*85.38* 33,384	*85.38* 33,384
EFH-8	**239.00**	**EA**	*149.52* **35,735**	*54.44* **13,011**	*451.50* **107,909**	*655.46* **156,655**	*655.46* **156,655**
USR Super Ball-Material	239.00	EA	*0.00* 0	*0.00* 0	*451.50* 107,909	*451.50* 107,909	*451.50* 107,909
USR LdLg Load Large Balls onto Truck @ Plant	239.00	EA	*6.82* 1,630	*4.64* 1,109	*0.00* 0	*11.46* 2,740	*11.46* 2,740
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	239.00	EA	*9.29* 2,221	*13.08* 3,126	*0.00* 0	*22.37* 5,347	*22.37* 5,347
USR StkLg Unload Large Balls & Stockpile	239.00	EA	*6.82* 1,630	*4.64* 1,109	*0.00* 0	*11.46* 2,740	*11.46* 2,740
USR BrgBy8 Load Large Balls into Barge RH-8	239.00	EA	*53.41* 12,764	*15.40* 3,681	*0.00* 0	*68.81* 16,445	*68.81* 16,445
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	239.00	EA	*73.18* 17,489	*16.68* 3,986	*0.00* 0	*89.85* 21,475	*89.85* 21,475
EFH-9	**46.00**	**EA**	*158.08* **7,271**	*56.61* **2,604**	*451.50* **20,769**	*666.19* **30,645**	*666.19* **30,645**
USR Super Ball-Material	46.00	EA	*0.00* 0	*0.00* 0	*451.50* 20,769	*451.50* 20,769	*451.50* 20,769
USR LdLg Load Large Balls onto Truck @ Plant	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	46.00	EA	*9.29* 428	*13.08* 602	*0.00* 0	*22.37* 1,029	*22.37* 1,029
USR StkLg Unload Large Balls & Stockpile	46.00	EA	*6.82* 314	*4.64* 213	*0.00* 0	*11.46* 527	*11.46* 527
USR BrgBy9 Load Large Balls into Barge RH-9	46.00	EA	*57.02* 2,623	*16.44* 756	*0.00* 0	*73.46* 3,379	*73.46* 3,379
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	46.00	EA	*78.12* 3,594	*17.81* 819	*0.00* 0	*95.93* 4,413	*95.93* 4,413

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Ultra	**337.00**	**EA**	*147.32* **49,648**	*53.98* **18,192**	*390.81* **131,702**	*592.11* **199,542**	*592.11* **199,542**
EFH-5, 6, & 7	**196.00**	**EA**	*143.22* **28,070**	*52.84* **10,357**	*388.50* **76,146**	*584.56* **114,574**	*584.56* **114,574**
USR Ultra Reef Ball-Material	196.00	EA	*0.00* 0	*0.00* 0	*388.50* 76,146	*388.50* 76,146	*388.50* 76,146
USR LdLg Load Large Balls onto Truck @ Plant	196.00	EA	*6.82* 1,337	*4.64* 910	*0.00* 0	*11.46* 2,247	*11.46* 2,247
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	196.00	EA	*9.29* 1,822	*13.08* 2,563	*0.00* 0	*22.37* 4,385	*22.37* 4,385
USR StkLg Unload Large Balls & Stockpile	196.00	EA	*6.82* 1,337	*4.64* 910	*0.00* 0	*11.46* 2,247	*11.46* 2,247
USR BrgBy5 Load Large Balls into Barge RH--5, RH-6, & RH-7	196.00	EA	*50.75* 9,946	*14.64* 2,869	*0.00* 0	*65.38* 12,815	*65.38* 12,815
USR PlcBy5 Transport Large Balls by Barge & Place- Site RH-5, RH-6, & RH-7	196.00	EA	*69.53* 13,628	*15.85* 3,106	*0.00* 0	*85.38* 16,734	*85.38* 16,734
EFH-8	**120.00**	**EA**	*149.52* **17,942**	*54.44* **6,533**	*388.50* **46,620**	*592.46* **71,095**	*592.46* **71,095**
USR Ultra Reef Ball-Material	120.00	EA	*0.00* 0	*0.00* 0	*388.50* 46,620	*388.50* 46,620	*388.50* 46,620
USR LdLg Load Large Balls onto Truck @ Plant	120.00	EA	*6.82* 819	*4.64* 557	*0.00* 0	*11.46* 1,375	*11.46* 1,375
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	120.00	EA	*9.29* 1,115	*13.08* 1,569	*0.00* 0	*22.37* 2,685	*22.37* 2,685
USR StkLg Unload Large Balls & Stockpile	120.00	EA	*6.82* 819	*4.64* 557	*0.00* 0	*11.46* 1,375	*11.46* 1,375
USR BrgBy8 Load Large Balls into Barge RH-8	120.00	EA	*53.41* 6,409	*15.40* 1,848	*0.00* 0	*68.81* 8,257	*68.81* 8,257
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	120.00	EA	*73.18* 8,781	*16.68* 2,001	*0.00* 0	*89.85* 10,782	*89.85* 10,782
EFH-9	**23.00**	**EA**	*158.08* **3,636**	*56.61* **1,302**	*388.50* **8,936**	*603.19* **13,873**	*603.19* **13,873**
USR Ultra Reef Ball-Material	23.00	EA	*0.00* 0	*0.00* 0	*388.50* 8,936	*388.50* 8,936	*388.50* 8,936

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	23.00	EA	157	107	0	264	264
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	23.00	EA	214	301	0	515	515
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	23.00	EA	157	107	0	264	264
			57.02	*16.44*	*0.00*	*73.46*	*73.46*
USR BrgBy9 Load Large Balls into Barge RH-9	23.00	EA	1,311	378	0	1,690	1,690
			78.12	*17.81*	*0.00*	*95.93*	*95.93*
USR PlcBy9 Transport Large Balls by Barge & Place- Site RH-9	23.00	EA	1,797	410	0	2,206	2,206
			312.58	*95.77*	*1,049.95*	*1,458.30*	*1,458.30*
EFH Large Balls Soft Foundation	**1,789.00**	**EA**	**559,209**	**171,332**	**1,878,360**	**2,608,900**	**2,608,900**
			326.27	*99.24*	*1,108.80*	*1,534.31*	*1,534.31*
Goliath	**716.00**	**EA**	**233,609**	**71,055**	**793,901**	**1,098,564**	**1,098,564**
			149.52	*54.44*	*504.00*	*707.96*	*707.96*
EFH-8	**716.00**	**EA**	**107,056**	**38,980**	**360,864**	**506,900**	**506,900**
			0.00	*0.00*	*504.00*	*504.00*	*504.00*
USR Goliath Reef Ball-Material	716.00	EA	0	0	360,864	360,864	360,864
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR LdLg Load Large Balls onto Truck @ Plant	716.00	EA	4,884	3,323	0	8,207	8,207
			9.29	*13.08*	*0.00*	*22.37*	*22.37*
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	716.00	EA	6,655	9,364	0	16,019	16,019
			6.82	*4.64*	*0.00*	*11.46*	*11.46*
USR StkLg Unload Large Balls & Stockpile	716.00	EA	4,884	3,323	0	8,207	8,207
			53.41	*15.40*	*0.00*	*68.81*	*68.81*
USR BrgBy8 Load Large Balls into Barge EFH-8	716.00	EA	38,238	11,029	0	49,267	49,267
			73.18	*16.68*	*0.00*	*89.85*	*89.85*
USR PlcBy8 Transport Large Balls by Barge & Place- Site EFH-8	716.00	EA	52,394	11,942	0	64,335	64,335
			176.75	*44.80*	*604.80*	*826.35*	*826.35*
Marine Mattress Mats	**716.00**	**EA**	**126,553**	**32,075**	**433,037**	**591,665**	**591,665**
			74.57	*21.51*	*0.00*	*96.08*	*96.08*
USR MMMk Load Gabion onto Barge	716.00	EA	53,393	15,400	0	68,793	68,793
			102.18	*23.29*	*0.00*	*125.47*	*125.47*
USR MMPlc Transport & Place in Water	716.00	EA	73,160	16,675	0	89,834	89,834
			0.00	*0.00*	*604.80*	*604.80*	*604.80*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR Marine Mattress 8'x8'x12"- material	716.00	EA	0	0	433,037	433,037	433,037
Super	**716.00**	**EA**	*326.27* **233,609**	*99.24* **71,055**	*1,056.30* **756,311**	*1,481.81* **1,060,974**	*1,481.81* **1,060,974**
EFH-8	**716.00**	**EA**	*149.52* **107,056**	*54.44* **38,980**	*451.50* **323,274**	*655.46* **469,310**	*655.46* **469,310**
USR Super Ball-Material	716.00	EA	*0.00* 0	*0.00* 0	*451.50* 323,274	*451.50* 323,274	*451.50* 323,274
USR LdLg Load Large Balls onto Truck @ Plant	716.00	EA	*6.82* 4,884	*4.64* 3,323	*0.00* 0	*11.46* 8,207	*11.46* 8,207
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	716.00	EA	*9.29* 6,655	*13.08* 9,364	*0.00* 0	*22.37* 16,019	*22.37* 16,019
USR StkLg Unload Large Balls & Stockpile	716.00	EA	*6.82* 4,884	*4.64* 3,323	*0.00* 0	*11.46* 8,207	*11.46* 8,207
USR BrgBy8 Load Large Balls into Barge RH-8	716.00	EA	*53.41* 38,238	*15.40* 11,029	*0.00* 0	*68.81* 49,267	*68.81* 49,267
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	716.00	EA	*73.18* 52,394	*16.68* 11,942	*0.00* 0	*89.85* 64,335	*89.85* 64,335
Marine Mattress Mats	**716.00**	**EA**	*176.75* **126,553**	*44.80* **32,075**	*604.80* **433,037**	*826.35* **591,665**	*826.35* **591,665**
USR MMMk Load Gabion onto Barge	716.00	EA	*74.57* 53,393	*21.51* 15,400	*0.00* 0	*96.08* 68,793	*96.08* 68,793
USR MMPlc Transport & Place in Water	716.00	EA	*102.18* 73,160	*23.29* 16,675	*0.00* 0	*125.47* 89,834	*125.47* 89,834
USR Marine Mattress 8'x8'x12"- material	716.00	EA	*0.00* 0	*0.00* 0	*604.80* 433,037	*604.80* 433,037	*604.80* 433,037
Ultra	**357.00**	**EA**	*257.68* **91,992**	*81.85* **29,222**	*919.18* **328,148**	*1,258.72* **449,362**	*1,258.72* **449,362**
EFH-8	**357.00**	**EA**	*149.52* **53,378**	*54.44* **19,436**	*388.50* **138,695**	*592.46* **211,508**	*592.46* **211,508**
USR Ultra Reef Ball-Material	357.00	EA	*0.00* 0	*0.00* 0	*388.50* 138,695	*388.50* 138,695	*388.50* 138,695
USR LdLg Load Large Balls onto Truck @ Plant	357.00	EA	*6.82* 2,435	*4.64* 1,657	*0.00* 0	*11.46* 4,092	*11.46* 4,092
USR TkLg Transport Ultra / Super / Goliath Balls-Truck	357.00	EA	*9.29* 3,318	*13.08* 4,669	*0.00* 0	*22.37* 7,987	*22.37* 7,987

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
USR StkLg Unload Large Balls & Stockpile	357.00	EA	*6.82* 2,435	*4.64* 1,657	*0.00* 0	*11.46* 4,092	*11.46* 4,092
USR BrgBy8 Load Large Balls into Barge RH-8	357.00	EA	*53.41* 19,066	*15.40* 5,499	*0.00* 0	*68.81* 24,565	*68.81* 24,565
USR PlcBy8 Transport Large Balls by Barge & Place- Site RH-8	357.00	EA	*73.18* 26,124	*16.68* 5,954	*0.00* 0	*89.85* 32,078	*89.85* 32,078
Marine Mattress Mats	**357.00**	**EA**	*108.16* **38,613**	*27.41* **9,786**	*530.68* **189,454**	*666.26* **237,853**	*666.26* **237,853**
USR MMMk6 Load Gabion onto Barge 6'x6'	357.00	EA	*45.63* 16,291	*13.16* 4,699	*0.00* 0	*58.80* 20,990	*58.80* 20,990
USR MMPlc6 Transport & Place in Water 6'x6'	357.00	EA	*62.53* 22,322	*14.25* 5,088	*0.00* 0	*76.78* 27,410	*76.78* 27,410
USR Marine Mattress 6'x6' x6"- material	716.00	EA	*0.00* 0	*0.00* 0	*264.60* 189,454	*264.60* 189,454	*264.60* 189,454
Contract 2 - SAV Initial Construction	**1.00**	**EA**	*24,825.00* **24,825**	*0.00* **0**	*0.00* **0**	*90,285.00* **90,285**	*90,285.00* **90,285**
SAV Pilot Construction-Phase 1	**1.00**	**EA**	*8,275.00* **8,275**	*0.00* **0**	*0.00* **0**	*30,095.00* **30,095**	*30,095.00* **30,095**
SAV's - Submerged Aquatic Vegetation	**287.98**	**ACR**	*28.73* **8,275**	*0.00* **0**	*0.00* **0**	*104.50* **30,095**	*104.50* **30,095**
SAV1,2,3 Max Main Stem/Max Broad Bay	**93.76**	**ACR**	*88.26* **8,275**	*0.00* **0**	*0.00* **0**	*320.98* **30,095**	*320.98* **30,095**
Restore SAV's -Contract 2, Pilot Studies	**1.00**	**EA**	*8,275.00* **8,275**	*0.00* **0**	*0.00* **0**	*30,095.00* **30,095**	*30,095.00* **30,095**
Restore SAV	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*21,820.00* **21,820**	*21,820.00* **21,820**
USR Mobilization	1.00	LS	0	0	0	320	320
USR SAV restoration	1.00	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*21,500.00* 21,500	*21,500.00* 21,500
Adaptive Management-SAV	**1.00**	**EA**	*8,275.00* **8,275**	*0.00* **0**	*0.00* **0**	*8,275.00* **8,275**	*8,275.00* **8,275**
Initial Assessment	**1.00**	**EA**	*8,275.00* **8,275**	*0.00* **0**	*0.00* **0**	*8,275.00* **8,275**	*8,275.00* **8,275**
USR Initial Assessment SAV Sites	1.00	YR	*8,275.00* 8,275	*0.00* 0	*0.00* 0	*8,275.00* 8,275	*8,275.00* 8,275

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			8,275.00	*0.00*	*0.00*	*30,095.00*	*30,095.00*
SAV Pilot Construction-Phase 2	**1.00**	**EA**	**8,275**	**0**	**0**	**30,095**	**30,095**
			28.73	*0.00*	*0.00*	*104.50*	*104.50*
SAV's - Submerged Aquatic Vegetation	**287.98**	**ACR**	**8,275**	**0**	**0**	**30,095**	**30,095**
			88.26	*0.00*	*0.00*	*320.98*	*320.98*
SAV1,2,3 Max Main Stem/Max Broad Bay	**93.76**	**ACR**	**8,275**	**0**	**0**	**30,095**	**30,095**
			8,275.00	*0.00*	*0.00*	*30,095.00*	*30,095.00*
Restore SAV's -Contract 2, Pilot Studies	**1.00**	**EA**	**8,275**	**0**	**0**	**30,095**	**30,095**
			0.00	*0.00*	*0.00*	*21,820.00*	*21,820.00*
Restore SAV	**1.00**	**EA**	**0**	**0**	**0**	**21,820**	**21,820**
USR Mobilization	1.00	LS	0	0	0	320	320
			0.00	*0.00*	*0.00*	*21,500.00*	*21,500.00*
USR SAV restoration	1.00	ACR	0	0	0	21,500	21,500
			8,275.00	*0.00*	*0.00*	*8,275.00*	*8,275.00*
Adaptive Management-SAV	**1.00**	**EA**	**8,275**	**0**	**0**	**8,275**	**8,275**
			8,275.00	*0.00*	*0.00*	*8,275.00*	*8,275.00*
Initial Assessment	**1.00**	**EA**	**8,275**	**0**	**0**	**8,275**	**8,275**
			8,275.00	*0.00*	*0.00*	*8,275.00*	*8,275.00*
USR Initial Assessment SAV Sites	1.00	YR	8,275	0	0	8,275	8,275
			8,275.00	*0.00*	*0.00*	*30,095.00*	*30,095.00*
SAV Pilot Construction-Phase 3	**1.00**	**EA**	**8,275**	**0**	**0**	**30,095**	**30,095**
			28.73	*0.00*	*0.00*	*104.50*	*104.50*
SAV's - Submerged Aquatic Vegetation	**287.98**	**ACR**	**8,275**	**0**	**0**	**30,095**	**30,095**
			88.26	*0.00*	*0.00*	*320.98*	*320.98*
SAV1,2,3 Max Main Stem/Max Broad Bay	**93.76**	**ACR**	**8,275**	**0**	**0**	**30,095**	**30,095**
			8,275.00	*0.00*	*0.00*	*30,095.00*	*30,095.00*
Restore SAV's -Contract 2, Pilot Studies	**1.00**	**EA**	**8,275**	**0**	**0**	**30,095**	**30,095**
			0.00	*0.00*	*0.00*	*21,820.00*	*21,820.00*
Restore SAV	**1.00**	**EA**	**0**	**0**	**0**	**21,820**	**21,820**
USR Mobilization	1.00	LS	0	0	0	320	320
			0.00	*0.00*	*0.00*	*21,500.00*	*21,500.00*
USR SAV restoration	1.00	ACR	0	0	0	21,500	21,500
			8,275.00	*0.00*	*0.00*	*8,275.00*	*8,275.00*
Adaptive Management-SAV	**1.00**	**EA**	**8,275**	**0**	**0**	**8,275**	**8,275**

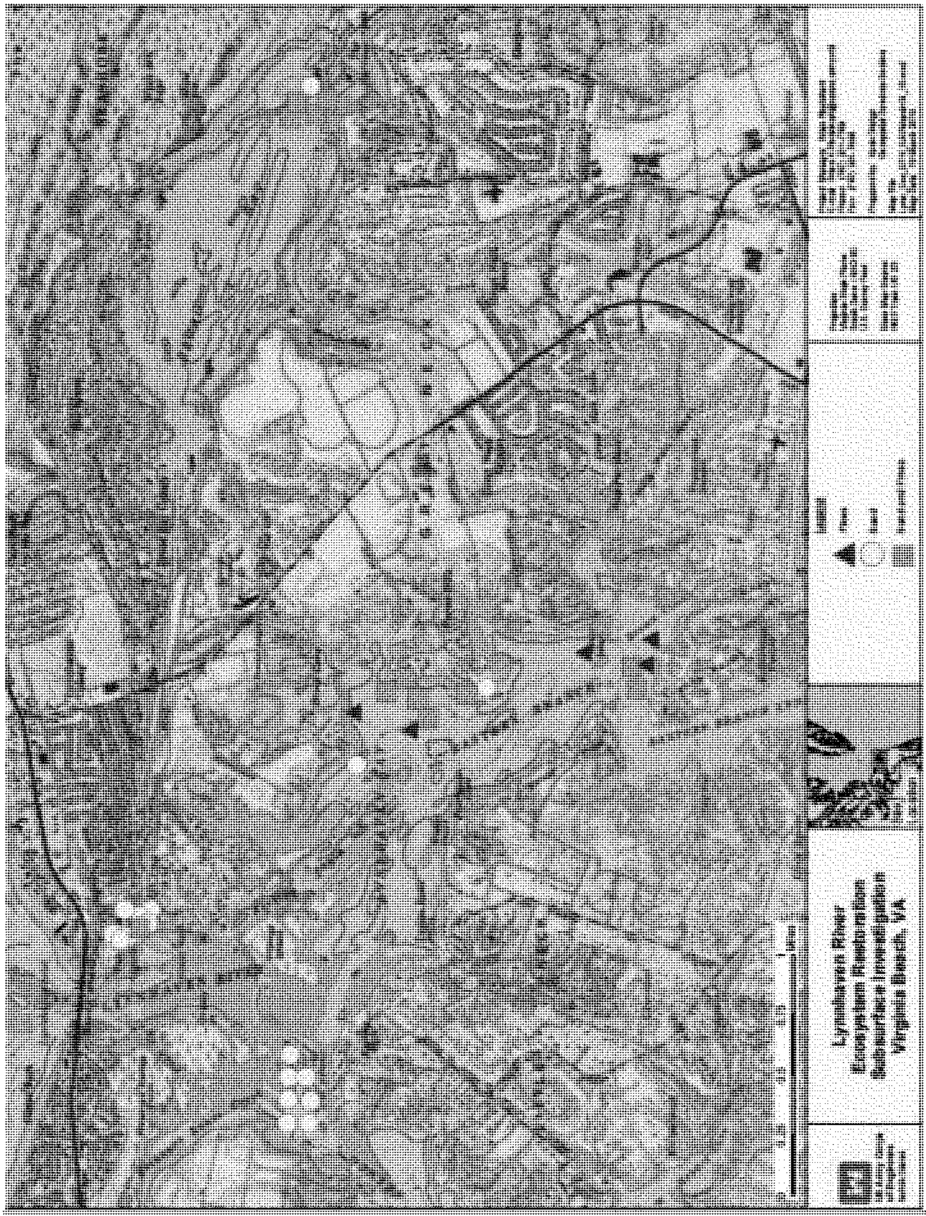
Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Initial Assessment	**1.00**	**EA**	*8,275.00* **8,275**	*0.00* **0**	*0.00* **0**	*8,275.00* **8,275**	*8,275.00* **8,275**
USR Initial Assessment SAV Sites	1.00	YR	*8,275.00* 8,275	*0.00* 0	*0.00* 0	*8,275.00* 8,275	*8,275.00* 8,275
Contract 3 - SAV Construction & Bay Scallops	**1.00**	**EA**	*37,500.00* **37,500**	*0.00* **0**	*0.00* **0**	*2,311,745.75* **2,311,746**	*2,311,745.75* **2,311,746**
SAV's - Submerged Aquatic Vegetation	**287.98**	**ACR**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*6,883.60* **1,982,340**	*6,883.60* **1,982,340**
SAV1,2,3 Max Main Stem/Max Broad Bay	**93.76**	**ACR**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*21,142.70* **1,982,340**	*21,142.70* **1,982,340**
SAV Large Scale Construction Phase 1, Contract 3	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*991,170.00* **991,170**	*991,170.00* **991,170**
Restore SAV	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*991,170.00* **991,170**	*991,170.00* **991,170**
USR Mobilization	1.00	LS	0	0	0	15,500	15,500
USR SAV restoration	45.38	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*21,500.00* 975,670	*21,500.00* 975,670
SAV Large Scale Construction Phase 2, Contract 3	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*991,170.00* **991,170**	*991,170.00* **991,170**
Restore SAV	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*991,170.00* **991,170**	*991,170.00* **991,170**
USR Mobilization	1.00	LS	0	0	0	15,500	15,500
USR SAV restoration	45.38	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*21,500.00* 975,670	*21,500.00* 975,670
Bay Scallop	**1.00**	**EA**	*37,500.00* **37,500**	*0.00* **0**	*0.00* **0**	*329,405.75* **329,406**	*329,405.75* **329,406**
Scallops Adults Collected Pilot- Phase 1, Contract 3	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*20,887.30* **20,887**	*20,887.30* **20,887**
Adults	**23,029.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*0.91* **20,887**	*0.91* **20,887**
USR Adult Bay Scallops-Racks	23,029.00	EA	*0.00* 0	*0.00* 0	*0.00* 0	*0.83* 19,114	*0.83* 19,114
USR Adult Bay Scallops-Set free	23,029.00	EA	*0.00* 0	*0.00* 0	*0.00* 0	*0.08* 1,773	*0.08* 1,773

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
Scallops Stock Juveniles Pilot - Phase 2, Contract 3	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*46,547.00* **46,547**	*46,547.00* **46,547**
Juveniles	**0.77**	**ACR**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*36,100.00* **27,797**	*36,100.00* **27,797**
USR Juvenile Bay Scallops	0.77	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*36,100.00* 27,797	*36,100.00* 27,797
Adapt Manage-Scallops	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*18,750.00* **18,750**	*18,750.00* **18,750**
Initial Assessment	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*18,750.00* **18,750**	*18,750.00* **18,750**
USR Initial Assessment Scallop Sites	1.00	YR	*18,750.00* 18,750	*0.00* 0	*0.00* 0	*18,750.00* 18,750	*18,750.00* 18,750
Scallops Stock Juveniles Pilot - Phase 3, Contract 3	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*46,547.00* **46,547**	*46,547.00* **46,547**
Juveniles	**0.77**	**ACR**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*36,100.00* **27,797**	*36,100.00* **27,797**
USR Juvenile Bay Scallops	0.77	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*36,100.00* 27,797	*36,100.00* 27,797
Adapt Manage-Scallops	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*18,750.00* **18,750**	*18,750.00* **18,750**
Initial Assessment	**1.00**	**EA**	*18,750.00* **18,750**	*0.00* **0**	*0.00* **0**	*18,750.00* **18,750**	*18,750.00* **18,750**
USR Initial Assessment Scallop Sites	1.00	YR	*18,750.00* 18,750	*0.00* 0	*0.00* 0	*18,750.00* 18,750	*18,750.00* 18,750
Scallops Stock Juv & Place Adults Large Scale - Phase 4, Contract 3	**1.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*215,424.45* **215,424**	*215,424.45* **215,424**
Juveniles	**0.76**	**ACR**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*36,100.00* **27,436**	*36,100.00* **27,436**
USR Juvenile Bay Scallops	0.76	ACR	*0.00* 0	*0.00* 0	*0.00* 0	*36,100.00* 27,436	*36,100.00* 27,436
Adults	**207,264.00**	**EA**	*0.00* **0**	*0.00* **0**	*0.00* **0**	*0.91* **187,988**	*0.91* **187,988**
USR Adult Bay Scallops-Racks	207,264.00	EA	*0.00* 0	*0.00* 0	*0.00* 0	*0.83* 172,029	*0.83* 172,029

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectCost	DirectCost
			0.00	*0.00*	*0.00*	*0.08*	*0.08*
USR Adult Bay Scallops-Set free	207,264.00	EA	0	0	0	15,959	15,959

Description	Page

PLATE 1

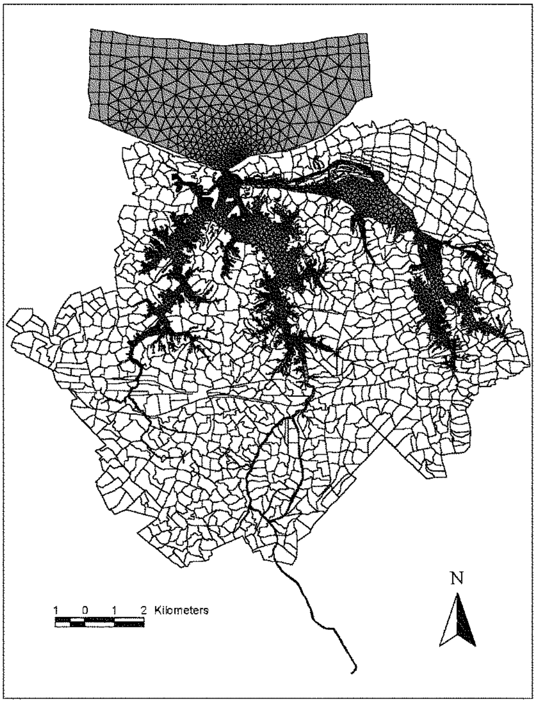


APPENDIX A

ATTACHMENT 1

DEVELOPMENT OF THE HYDRODYNAMIC AND WATER QUALITY MODELS FOR THE LYNNHAVEN RIVER SYSTEM

Development of Hydrodynamic and Water Quality Models for the Lynnhaven River System



Mac Sisson, Harry Wang, Yuepeng Li, Jian Shen, Albert Kuo,
Wenping Gong, Mark Brush, and Ken Moore

Final Report to the
U. S. Army Corps of Engineers, Fort Norfolk Office
and
The City of Virginia Beach

Special Report No. 408
In Applied Marine Science and Ocean Engineering

Virginia Institute of Marine Science
Department of Physical Sciences
Gloucester Point, Virginia 23062

November 2010

EXECUTIVE SUMMARY

"Development of Hydrodynamic and Water Quality Models for the Lynnhaven River System"

1. The Norfolk District of the US Army Corps of Engineers and the City of Virginia Beach are working together on a cost-shared basis for the feasibility study of the Lynnhaven River environmental restoration. In January 2005, these agencies contracted with the Virginia Institute of Marine Science (VIMS) for the development of hydrodynamic and water quality models for the Lynnhaven River System.

2. VIMS has performed a successful development of an integrated numerical modeling framework for the Lynnhaven River. This framework combines a high-resolution 3D hydrodynamic model (UNTRIM) that provides the required transport for a water quality model (CE-QUAL-ICM) that, in turn, provides intra-tidal predictions of 23 water quality state variables.

3. Prior to the inception of the project, all available historical Lynnhaven hydrodynamic and water quality data were amassed in a MicroSoft ACCESS database and analyzed for model calibration suitability and long-term trends. These data were collected from monitoring programs of the Virginia Department of Environmental Quality (VA-DEQ) and the Virginia Health Department, Shellfish Sanitation Division (VA-DSS), intensive surveys conducted by VIMS and Malcolm Pirnie Environmental Engineers, and tidal surveys conducted by the National Oceanic and Atmospheric Administration (NOAA).

4. A strategy of project-specific field surveys and laboratory experiments was devised based on which measurements would complement the existing historical data and be most useful to the model calibration and validation processes. These field surveys included the following:

- a hydrodynamic survey of synoptic measurements of times series of surface elevations plus currents and salinities in all Lynnhaven branches and outside the Inlet
- seasonal sediment flux measurements at the Inlet and in all branches to determine the spatial and seasonal variations of the fluxes from the water column to the sediment (and vice versa) of dissolved oxygen, ammonia, nitrate-nitrite, and phosphate
- sediment flux measurements of dissolved oxygen, ammonia, nitrate and nitrite, and phosphate in the laboratory under controlled environments
- critical shear stress measurements at multiple sites in the basin to determine the spatial and seasonal variations to the erodibility of bottom sediments
- high-frequency time series measurements of chlorophyll-a, turbidity, Colored Dissolved Organic Matter (CDOM), and dissolved oxygen (DO) to evaluate water quality conditions with high temporal resolution

5. The hydrodynamic model was calibrated using historical datasets and NOAA tide predictions. The water quality model was calibrated using the 2006 dataset collected by the VA-DEQ.

(a) Calibration of the hydrodynamic model

Calibration of the hydrodynamic model for tides was performed by comparing model results with synoptic measurements at 5 locations spanning from Long Creek to Broad Bay to Linkhorn Bay, as well as by comparing the NOAA predicted tide ranges and phases to model results at two Western Branch stations (Bayville Creek and Buchanan Creek) and one Eastern Branch location (Brown Cove). Calibration for velocity was made by comparing model predictions with high-frequency measurements made in 2003 at two locations bounding Long Creek. Calibrations for both temperature and salinity were made throughout 2006 by comparing model predictions with observations made at the 16 Lynnhaven VA-DEQ stations monitored every other month.

(b) Calibration of the water quality model

Calibration of the water quality model was performed for 2006 by comparing model predictions with measurements taken every other month at the 16 Lynnhaven DEQ stations for the parameters of dissolved oxygen (DO), chlorophyll-a (chl-a), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ammonium (NH_4), nitrate-nitrite (NO_3), and ortho phosphorus (PO_4).

6. Validation of the hydrodynamic model was made by comparing the 2005 simulation results with observations collected in VIMS hydrodynamic surveys of that year. Validation of the water quality model used the two-year period 2004-2005 as the period of validation. No adjustments to the values of calibration parameters, which were set in the calibration process, were made in the validation process.

(a) Validation of the hydrodynamic model

Validation for water surface elevations was made by making a 30-day, high-frequency comparison of model predictions to observations at the Virginia Pilot's Station just inside the Inlet and a 16-day, high-frequency comparison of predictions to observations at West Neck Creek, Upper Eastern Branch. Validation of velocities was made by comparing model predictions to 30-day measurements of velocity at representative locations in each branch as well as at surface, middle, and bottom layers of a station in the channel just outside of the Inlet. Validations for both temperature and salinity were made throughout 2004-2005 by comparing model predictions with observations made at the 16 Lynnhaven VA-DEQ stations monitored every other month.

(b) Validation of the water quality model

Validation of the water quality model was performed for 2004-2005 by comparing model predictions with measurements taken every other month at the 16 Lynnhaven VA-DEQ stations for the water quality variables of dissolved oxygen (DO), chlorophyll-a (chl-a), total

Kjeldahl nitrogen (TKN), total phosphorus (TP), ammonium (NH_4), nitrate-nitrite (NO_3), and ortho phosphorus (PO_4).

7. A sediment transport model utilizing the equilibrium critical shear stress defined at the interface between layers was incorporated into the modeling framework. This model was calibrated by comparing its predictions of total suspended solids (TSS) with observations at the 16 Lynnhaven DEQ stations during 2006 and validated by comparing the 2004-2005 model results with DEQ observations for those years. Additionally, the validation compared model predictions with TSS values derived from VIMS high-frequency measurements of turbidity at 3 locations in 2005.

8. The major findings of the study included degraded water clarity due to significant concentrations of suspended sediment and localized summertime dissolved oxygen problems in headland areas. VIMS is attempting to assess the impacts that these conditions have on the restoration effort by conducting sensitivity tests of the model to reductions in the sediment and nutrient loadings associated with these conditions.

9. The entire modeling framework has been calibrated and validated and has been prepared for its application in conducting scenario runs. The models thus become a management tool for environmental assessments of the effects of variations in nutrient and sediment loadings, and other mitigation practices, in the Lynnhaven River system.

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CHAPTER I. BACKGROUND

The Lynnhaven River system, comprised of the Eastern, Western Branches, Broad Bay, and Linkhorn Bay, is a shallow-water coastal system located near the southeast corner of the Chesapeake Bay. It traverses a 64-square-mile watershed that spans most of the northern half of Virginia Beach with a land use that is 40% residential and 35% streets, commercial and office space, and military use, and it flows northerly and empties into the Chesapeake Bay about 10 miles east of Norfolk (see Figure I.1). Due to its narrow entrance and greater influence by the tide of the Bay than by river discharge, it is technically considered as a tidal inlet system. Like many Chesapeake Bay small coastal basins, the Lynnhaven River system was a highly productive ecosystem, supporting a large oyster population and various shallow water organisms. Clampitt et al. (1993) documented that 20 species of vertebrate, 39 invertebrate species, 76 plant species, and 19 types of rare natural communities of statewide significance are supported in the Lynnhaven. In the early twentieth century, Lynnhaven River was known for its abundant harvest of "oysters suitable for kings". The Lynnhaven oyster population has since drastically diminished along with water quality degradations that include poor water clarity, recession of submerged aquatic vegetation areas, and high chlorophyll, suspended solids, and seasonally-low dissolved oxygen levels in headland regions of the branches.

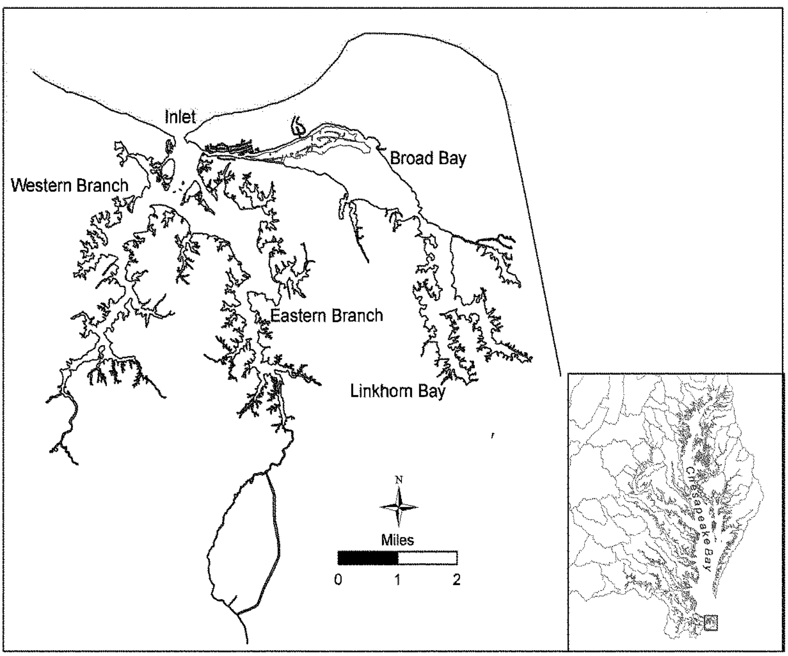


Figure I.1. Location of the Lynnhaven River in the Chesapeake Bay

In May 1998, the Lynnhaven River Environmental Restoration Study was authorized by Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives. Congress appropriated funding in 2002 to initiate a reconnaissance analysis in support of this authority. The ensuing reconnaissance report, issued by the U.S. Army Corps of Engineers (2002), cited a number of problems in water quality deterioration, siltation, sedimentation, and habitat management in the Lynnhaven. The report stated that "the river has become increasingly stressed as the watershed has experienced a shift from a predominantly rural to a predominantly urban/suburban land use pattern".

Over the past several decades, Lynnhaven River water quality has been degraded by increased volume and decreased quality of stormwater runoff. Non-point sources (NPS), such as storm drains, soil erosion, lawn fertilizer, street litter, estuarine sediments, animal wastes, and failing septic systems, have caused the most degradation. The reconnaissance report cites additional causes of Lynnhaven water quality degradation as including the loss of wetland buffers associated with shoreline hardening and erosion, degradation of riparian buffers near stormwater outfalls, increased siltation from land-based construction, and increased stormwater runoff due to more developments and roadways. Additional concerns regarding water quality in the Lynnhaven include water clarity and the levels of total suspended solids measured throughout the branches of the Lynnhaven as well as seasonally low dissolved oxygen and high fecal coliform levels measured in the upper Western and Eastern Branches, where the River's flushing capacity diminishes.

Whereas decreased water quality can have severe ecological impact on both benthic and pelagic populations and species diversity, there are additional ecological impacts emerging in the Lynnhaven. These impacts affect:

1) the abundance of tidal wetlands caused by construction activities such as dredging, filling, bulkheading, and channelization,
2) the oyster resources caused by high fecal coliform levels, and
3) the submerged aquatic vegetation (SAV) habitats caused by high nutrient and sediment inputs and the ensuing poor water clarity.

Another noteworthy issue regarding environmental restoration of the Lynnhaven includes siltation in the upper reaches, which has increased over the past several decades, and which can decrease the flushing capability upstream by decreasing the tidal prism. Lastly, sediments with elevated levels of heavy metals or other toxicants, which could severely impact living resources, have been noted in several Lynnhaven reports.

In an evaluation of alternative, the U.S. Army Corps of Engineers reconnaissance report determined that the alternatives would result in net environmental benefits through ecosystem restoration, and recommended that this study continue into its next phase, a cost-shared feasibility study.

The agencies in charge of the present development efforts are the Norfolk District, U.S. Army Corps of Engineers (ACE), representing the Federal Government, and the City of Virginia Beach, acting as the Local Sponsor. These agencies signed a feasibility cost-sharing agreement and embarked on determining suitable and acceptable means for designing and implementing the environmental restoration of the Lynnhaven. During discussions with personnel from VIMS and URS Corporation of Virginia Beach, it was resolved that a fully comprehensive system, including spatially high-resolution numerical modeling and watershed loading estimation, was required in order to address the issues cited in the reconnaissance report and to provide the management option of a control strategy of attaining the required endpoints for environmental restoration.

In early 2005, the ACE (Norfolk District) and the City of Virginia Beach contracted with VIMS for the development of hydrodynamic and water quality models for the Lynnhaven River System receiving waters and with URS Corporation for the development of a watershed model to provide both freshwater flows and nutrient and sediment loadings from the Lynnhaven River Basin.

CHAPTER II. INTRODUCTION

The Lynnhaven River system is an extremely shallow waterbody with average depths of only 0.62 m, 0.75 m, and 2.16 m, respectively, is the Western, Eastern, and Broad Bay/Linkhorn Bay systems (Figure II.1). It is also characterized by a narrow Inlet opening and tidal flats, small islands, and branching shorelines in its branches.
The shallow water portion of the coastal system (with water depths less than 2-3 meters) is ubiquitous along the edge of the shoreline and many coastal embayments. Its habitat supports a tremendous diversity of aquatic life, including plants, benthos, invertebrates, plankton, crabs, fish, and seabirds; in particular, it serves as the major fish spawning ground providing shelter and food sources. Therefore, the shallow water region (SWR) is a unique habitat and an integral part of the productivity of the Bay ecosystem.

The SWR is the buffer zone between aquatic and terrestrial landscapes. It has been shown that nonpoint sources of nutrient inputs, including groundwater and surface water runoff, that pass through this region contribute significantly to the overall eutrophication problem. Human activities in watersheds have caused major changes in water quality, resulting in increased loading of nutrients, organic matter, and sediment to the SWR (Fleischer, 1987; Frink, 1991; Hopkinson and Vallino, 1995). Industrial activities and agriculture generate a mixture of chemicals, including nutrients, some of which are inevitably discharged into aquatic ecosystems. As a result, the SWR, such as

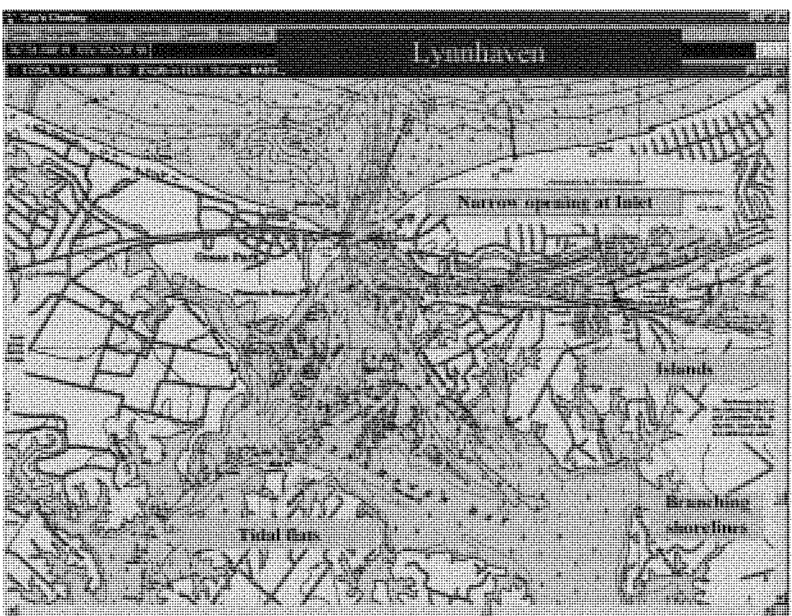


Figure II.1. Physical features of the Lynnhaven River sytem coastal lagoons and embayments, has received large inputs of nutrients from watershed due to anthropogenic activities for many years. Therefore, the SWR is a highly productive environment. Nutrient loading usually arises from sources including: fertilizer runoff, groundwater, sewage discharges, and aquaculture (Balls, 1994). Accordingly, there are increasing interests and demands for further understanding of eutrophication processes in the SWR.

The characteristics of the SWR differ from those of deepwater regions. The water table is usually at or near the surface, and it is constantly under the influence of tide, wave, and climate changes, which leads to wetting and drying of tidal flats, larger variation of salinity and nutrients change, suspension of sediment, and runoff of nutrients released from the land. The shallowness permits wind and tide-driven mixing to occur through the water column over the entire year. In deeper estuaries, stratification may be significant due to the high bottom salinity and sediment concentration. In the SWR system, however, continuous mixing causes the salinity stratification to become almost vertically homogeneous. Meanwhile, vertically well-mixed conditions also resuspend sediment material, including the nutrients required for primary productivity, to the overlying water column. Thus, the potential for the primary productivity is increased. Shallowness also enables sunlight to penetrate to the bottom of the sediments, which creates favorable conditions for the benthic primary producers. Combining these two factors, the primary productivity usually is high in this shallow water system.

The dynamics of the SWR are very rich because of the input of mechanical energy (freshwater discharge, tide, and wind), solar radiation, and nutrients (nitrogen and phosphorus). These natural resources stimulate primary production in both the water column and the benthic zone of the SWR. In contrast to a pelagic system, the benthos of the SWR may provide an important source of nutrients because of both its shallowness and the vertical turbulence caused by wind and tidal agitation. The nutrient exchange across the sediment-water interface is an important pathway for nutrient cycles in the SWR. The evaluation of the exchange oxygen and nutrients flux is indispensable to identifying the effects of SWR estuaries or embayments (Reay et al., 1995; Sanders et al., 1997; Yin and Harrison, 2000). Therefore, benthic nutrient fluxes have long been recognized as being an important component of estuarine ecosystems due to their ability to significantly influence water quality (Nixon, 1981; Blackburn and Henriksen, 1983; Boynton and Kemp, 1985; Kemp et al., 1990; Rizzo and Christian, 1996).

Furthermore, benthic microalgae (BMA) influence several key estuarine biogeochemical processes. Through photosynthesis of BMA, the upper sediment is oxygenated. An increase in the sediment oxygenation can lead to an indirect influence on sediment biogeochemistry as anoxic microbial processes are pushed deeper (Sundbäck et al., 2000). Meanwhile, BMA also uptake nutrients to sustain their autotrophic processes (Rizzo, 1990; Rizzo et al., 1992; Sundbäck et al., 2000; Anderson et al., 2003). This has important implications for regenerated nutrients as the oxic state of sediments closely controls benthic nutrient regeneration (Boynton and Kemp, 1985; Rysgaard et al., 1994; Banta et al., 1995; Chapelle, 1995). Nutrient release from the sediments increases dramatically during hypoxic and anoxic events (Sundby et al., 1992; Cowan and Boynton, 1996).

Overall, in shallow portions of estuaries, BMA photosynthesis and respiration are important components of the entire ecosystem. Several studies indicated that BMA production could account for up to 50% of the entire system primary production in shallow estuarine and coastal waters (van Raalte et al., 1976; Sullivan and Moncrieff, 1988; Sundbäck and Jönsson, 1988), and benthic respiration accounts for 25% of the organic matter respired in various environments (Nixon, 1981). Nutrient loading, resulting from human activities, can also have significant impacts on benthic photosynthesis and respiration. Nutrient enrichment has been demonstrated to increase BMA production and biomass in field experiments (van Raalte et al., 1976; Granéli and Sundbäck, 1985).

The lagoons and shallow water estuaries can be exploited for recreational purposes, and for economic activities such as oyster restoration, crab rearing, and fish farming. It is very difficult to forecast the behaviour of a shallow water ecosystem, a complex network of relationships between plants and animals within a given environment, because of its complexity. The trophic network of this ecosystem is based on primary production, nutrient loading, and the amount of solar free energy, which is converted into biomass by means of photosynthesis. Primary production varies in space and in time, and depends on three important factors: water temperature, solar energy, and nutrients such as nitrogen and phosphorus in the aquatic system.

At a qualitative level, the role of each of these three factors in the ecosystem is well understood and it is common knowledge that the primary production depends on the interaction between these factors. However, it is difficult to quantify how much each of these factors would affect the year-to-year biomass production, and the occurrence of an anoxic crisis caused by excessive primary production. An integrated modeling approach has been successfully applied in the Chesapeake Bay for investigating hypoxia and anoxia over the deep water region in the mainstem Bay and major tributaries (Cerco et al., 2002). The approach calls for a system of models including hydrodynamic, watershed, water quality, and sediment flux models to be setup and operated in the study domain. The hydrodynamic model results provide transport information for the water quality model. Meanwhile, results from the watershed model will provide the nutrient loadings from land. The rates of nutrient exchange between sediment and the overlying water column are calculated from the sediment flux model.

The concern about eutrophication in coastal areas has prompted a large number of field and modeling studies on the dynamics of these environments. A number of historical surveys for water quality data collection and modeling studies for the Lynnhaven River have been conducted by the Virginia Institute of Marine Science (VIMS), Virginia Department of Environmental Quality, Department of Shellfish and Sanitation, and Malcolm Pirnie Engineers, over the past three decades. Previous modeling efforts used a simplified tidally averaged hydrodynamic component. An initial water quality study of Buchanan Creek, a small tributary in the Western Branch of Lynnhaven, was done by Ho et al. (1977a). Later, these researchers used both slack water surveys and intensive surveys to contrast the circulation in the Lynnhaven River System with that of nearby Little Creek Harbor (Ho et al., 1977b). Malcolm Pirnie Engineers (1980), in a report to the Norfolk District Army Corps of Engineers, described the conditions of Lynnhaven at that time, citing the expected problems as the watershed was further "built-out". In response, Kuo et al. (1982) applied the inter-tidal tidal prism model to study the effects of stormwater impacts on the water quality of the Lynnhaven. Later, Park et al. (1995a; 1995b), in work for the Virginia Department of Environmental Quality's (DEQ's) Coastal Resources Management Program, analyzed numerous surveys from 1980 and 1994 and further refined the tidal prism model.

Early models of sediment-water nutrients fluxes were based on net heterotrophic sediments and showed fluxes as primarily net nutrient sources to the water column (DiToro and Fitzpatrick, 1993). Flux measurements were also commonly made in the dark since there was no light available at the sediment surface, and benthic metabolism was driven by the heterotrophic breakdown of particulate organic matter derived from the water column (Davies, 1975). Recently, the importance of productivity by BMA in euphotic sediments was demonstrated (Colijn and de Jonge, 1984; Rizzo and Wetzel, 1985; Sundbäck, 1986), and autotrophic benthic production was shown to have direct and indirect impacts on benthic nutrient fluxes (Andersen et al., 1984; Sundbäck and Granéli, 1988; Anderson et al., 2003; Tyler et al., 2003). These included the direct assimilation of nutrients by benthic primary producers, as well as influencing microbial metabolism through modification of sediment biogeochemistry, for example, oxygen penetration (Revsbech et al., 1980; Rueter et al., 1986; Lorenzen et al., 1998). Therefore, several mathematical models were developed that vertically integrated the effects of oxygen penetration on benthic microbial processes (Christensen et al., 1989; 1990; Blackburn, 1990).

There are many challenges to modeling efforts in shallow water regions, in general, but particularly for the Lynnhaven River for several reasons:

1) the narrow opening at the Inlet
2) extensive tidal flats just inside the Inlet
3) 150 miles of meandering shorelines throughout the Lynnhaven
4) islands within this system.

These factors primarily affect the hydrodynamic modeling efforts. A key modeling challenge for any water quality application is the determination of whether all the vital mechanisms are accounted for in the selection of state variables in the model formulation. The pioneering work done by Li (2006) has demonstrated quantitatively the important role played by BMA for the shallow-water Lynnhaven River system.

With the given basin geometry, initial condition, and loading information from the surrounding watershed as the boundary conditions, the model framework solves the mathematical equations governing the processes. The results are then calibrated and verified with the observation data. When properly tuned, the modeling framework renders a holistic view of the system functions, can assess 'what-if' scenarios, and provides tremendous predictive capability to aid management decisions and scientific research. In a similar vein, there is an excellent opportunity to make use of the integrated modeling approach to study the shallow water processes in the coastal basins. The timing is particularly appropriate, given the new shallow water monitoring technologies with high spatial and temporal coverage that are emerging (http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm). This study attempts to address these difficulties by performing an integrated modeling approach, which mimics the main features of the shallow estuary. With this model, it is possible to capture the main dynamic features of the systems at a reasonable computational cost.

In order to explore these dynamics, a BMA model has been developed and uniquely coupled to the water column model that provides an otherwise comprehensive description of physical processes and both the benthic and pelagic marine trophic systems. For the water column, the well-tested CE-QUAL-ICM model was used. The relative complexity of CE-QUAL-ICM allows consideration of the full range of potential influences that BMA may have on the marine ecosystem. More recently, a robust finite difference/finite volume model for three-dimensional flows, UnTRIM (Unstructured Tidal Residual Intertidal Mudflat), has been formulated and tested on an unstructured orthogonal grid (Casulli and Zanolli, 1998; Casulli and Walters, 2000). UnTRIM, which uses an unstructured grid to better resolve complicated coastlines in the shallow environment, was further developed using the finite volume method calculation to ensure conservation of mass for all the physical and chemical constituents. UnTRIM provides hydrodynamic information that is needed by the water quality model, such as surface water elevation, three-dimensional velocity field, vertical eddy diffusivity, and so on.

An introduction has herein been presented in Chapter II. Chapter III provides a description of the methodology utilized during the project, from the overall numerical modeling framework to the individual interactive models. Chapter IV describes field observation data, both historical data and project-specific field measurements. The calibrations of the hydrodynamic and water quality models are presented in Chapter V and their validations are presented in Chapter VI. Chapter VII describes a sensitivity analysis on benthic microalgae dynamics. Lastly, Chapter VIII provides a discussion and conclusions.

CHAPTER III. NUMERICAL MODELING METHODOLOGY

III-1. Description of Numerical Modeling Framework

Numerical modeling, in a broad sense, is a process of building a mathematical abstraction of an actual system. In the estuarine and coastal environmental context, the system consists of physical, chemical, and biological components that are interactive and feed back on one another. The VIMS numerical modeling framework, as shown in Figure III.1, involves an integrated approach that combines several different processes such as hydrodynamic, water quality, nutrient, sediment processes in order to fully address the environmental impact. Whereas the CE-QUAL-ICM water quality model is shown to be the central processing mechanism, it depends heavily upon the other models with which it interacts:

1) the UnTRIM hydrodynamic model for mass and volume transport,
2) the HSPF watershed model for freshwater discharge and nutrient loadings, and
3) the sediment model for sediment flux information.

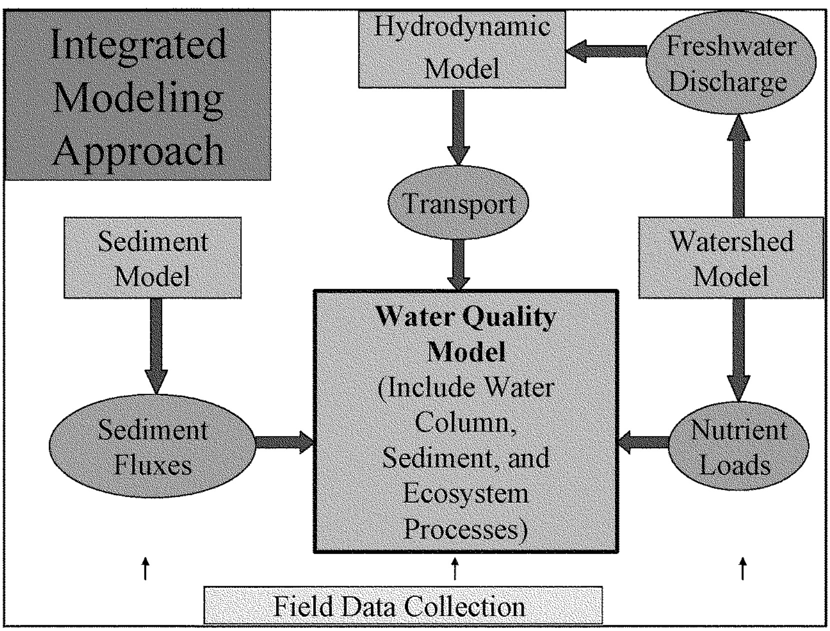


Figure III.1. The integrated modeling approach used for the VIMS water quality model

III-2. The UnTRIM hydrodynamic model

The hydrodynamic model selected for use in the numerical modeling framework is vital in that it provides the transport information required by the water quality model. The VIMS selection of UnTRIM as the hydrodynamic model for this project was based on several key features that make UnTRIM ideally suited for application to the Lynnhaven:

1) UnTRIM's use of an unstructured grid allows for a better fit of the meandering shorelines of the Lynnhaven branches
2) UnTRIM's efficient wetting-and-drying algorithm affords accurate representation of the intra-tidal areas in the system
3) UnTRIM's finite volume representation has the quality of conserving mass locally as well as globally
4) UnTRIM's independence from the Courant-Friedrich-Levy (CFL) stability criterion allows for the use of a comparatively long timestep for calculations (several minutes) despite maintaining high spatial resolutions on the order of 10 meters

III-2-1. Description of UnTRIM

The hydrodynamic model UnTRIM (Unstructured Tidal, Residual, and Intertidal Mudflat) was developed by Professor Vincenzo Casulli (Trento University, Italy). UnTRIM is a semi-implicit finite difference (-volume) model based on the three-dimensional shallow water equations as well as on the three-dimensional transport equation for salt, heat, dissolved matter and suspended sediments. UnTRIM is governed by the equations of motion, the equation of continuity, and the transport equation.

UnTRIM is able to work on unstructured orthogonal grids (UOG). The modeling domain is covered by a grid consisting of a set of non-overlapping convex polygons, usually either triangles or quadrilaterals. The grid is said to be an *unstructured orthogonal grid* if within each polygon a point (hereafter called a center) can be identified in such a way that the segment joining the center of two adjacent polygons and the side shared by the two polygons, have a non-empty intersection and are orthogonal to each other (Casulli and Zanolli, 1998).

UnTRIM has been widely used (Li, 2002; Li et al., 2004; Wang et al., 2004; Luckenbach et al., 2005; Sisson et al., 2005; Shen et al., 2006). The governing equations of UnTRIM are solved using a semi-implicit, finite difference/finite volume numerical scheme based on the three-dimensional shallow water equations as well as on the three-dimensional transport equation. Quantities computed by the model include three-dimensional velocities, surface elevation, vertical viscosity and diffusivity, salinity, and temperature. Li (2006) performed numerous rigorous tests comparing the inlet dynamics predicted from UnTRIM with the classic analytical solutions of Keulegan (1967), King (1974), and DiLorenzo (1988) using ideal cases.

The numerical algorithms of UnTRIM (Casulli and Zanolli, 1998; Casulli, 1999; Casulli and Walters, 2000; Casulli and Zanolli, 2002) are relatively straightforward, and yet general and robust. The detailed model description can be found in the above references. Compared with an unstructured finite element model, UnTRIM has a number of interesting properties, such as global and local mass conservation, high-order numerical accuracy, and unconditional stability.

An unstructured orthogonal grid differs from the orthogonal grid, such as that used by other models like the Hydrodynamic Eutrophication Model in 3 Dimensions (HEM-3D) or the Princeton Ocean Model (POM). The orthogonal grid used by HEM-3D and POM consist of only four-sided structured polygons, but UnTRIM can use both three- or four-sided polygons. As with other models, the horizontal computational domain must be covered with a set of non-overlapping convex three- or four-sided polygons. Each side of the polygon is either a boundary line or a side of an adjacent polygon.

The highest numerical accuracy is obtained when a uniform grid, composed of equilateral triangles or uniform quadrilaterals (i.e., rectangles), is used. In these cases, the normal velocity on each face of each polygon is located at the center point of the face and the centers of two adjacent polygons are equally spaced from the common face. Consequently, the discretization error is small. An unstructured, nonuniform grid can be used with a somewhat larger discretization error (Casulli and Zanolli, 1998). The error would be amplified as the simulation time is long enough, which is common in water quality simulation. However, this error can be minimized when the polygon size and shape variations through the flow domain are properly arranged. So, in order to take full advantage of the new flexibilities of the unstructured grid, the grid size and shape should change gradually.

In the UnTRIM numerical scheme, the local volume conservation is assured by the finite volume formulation. At the same time, a finite volume method is used to discretize the free-surface two-dimensional equation at each polygon. In this fashion, local and global volume conservation is guaranteed. The transport equations are solved by using the sub-cycle upwind scheme, or using a higher resolution scheme -- flux limiter method (Casulli and Zanolli, 2005). Therefore, when the transport equations are calculated, mass is also conserved locally and globally because a finite volume form is used.

The Eulerian–Lagrangian method (ELM), also known as the semi-Lagrangian method (SL), is applied in the UnTRIM numerical scheme to solve the momentum equations. It allows one to achieve a very accurate discretization of the nonlinear advection terms (Staniforth and Temperton, 1991). The advection term is solved by the Lagrangian method, which can be computed independently at each time step by the method of characteristics applied to a fixed grid domain. ELM is especially efficient when applied to unstructured Cartesian grids (Casulli and Walters, 2000; Casulli and Zanolli, 2002; Cheng et al., 1993). When momentum equations are solved, ELM combines the advantages of the Eulerian method and the Lagrangian method, by merging the simplicity of a fixed Eulerian grid with the computational power of the Lagrangian method. The advantage of ELM is that the sharp front of velocity or concentration is easier to trace since the system matrix becomes symmetric and diagonal (Casulli and Zanolli, 2002). Secondly, a large time step can be used, since the Courant number is not constrained by the small grid size (Casulli and Cattani, 1994; Casulli, 1999; Casulli and Walters, 2000; Casulli and Zanolli, 2002; Cheng and Casulli, 1996).

In applications to domains using the unstructured grid, there are two keys steps: approximation of the Lagrangian paths (characteristic streamlines) and interpolation at the departure point of the Lagrangian trajectory. The determination of the approximation of the characteristic streamline is solved using an integration method (Euler method) with a small time step shorter than the global time step. The method used by UnTRIM is called "Substepping" for the approximation of the backward trajectory (Casulli and Cattani, 1994; Casulli, 1999). In order to calculate the departure point, the bilinear interpolation is used by UnTRIM, which is sufficiently accurate.

The minimum grid size for a UnTRIM application can be as small as a few meters. However, due to its unconditional stability, UnTRIM can still use a very large timestep on the order of 10 minutes. Casulli and Cattani (1994) noted that the stability analysis of the semi-implicit finite difference method has been carried out in the case of barotropic and hydrostatic flow on a uniform rectangular grid. They assumed that the governing differential equations are linear, with constant coefficients, and are defined over an infinite horizontal domain. The analysis shows that the method is stable. Computational results of several test cases have indicated that no additional stability restrictions are required when a non-uniform unstructured mesh is used and when the hydrostatic assumption is removed. Thus, the stability of the present algorithm is independent of the celerity, wind stress, vertical viscosity, and bottom friction. It does depend on the discretization of the advection and horizontal viscosity terms. When an Eulerian-Lagrangian method is used for the explicit terms, a mild limitation on the time step depends on the horizontal viscosity coefficient and on the smallest polygon size. A further mild limitation on the time step is imposed in baroclinic flows because the baroclinic pressure term in the momentum equation has been discretized explicitly. This limitation is related to the internal wave speed that is typically smaller than the surface wave speed. This method becomes unconditionally stable for barotropic flows when the horizontal viscosity terms are neglected.

III-2-2. Formulation of UnTRIM governing equations

The UnTRIM model was developed by Casulli (1999). Detailed descriptions of the numerical algorithms of the model can by found in Casulli and Zanolli (1998), Casulli (1999), and Casulli and Walters (2000). In Cartesian coordinates, the governing continuity and momentum equations for three-dimensional flows solved by the model are:

$$\frac{\partial \mathbf{u}}{\partial x}+\frac{\partial \mathbf{v}}{\partial y}+\frac{\partial \mathbf{w}}{\partial z}=0 \qquad \text{(III-1)}$$

$$\frac{\partial \eta}{\partial t}+\frac{\partial}{\partial x}\int_{-h}^{\eta}\mathbf{u}dz+\frac{\partial}{\partial y}\int_{-h}^{\eta}\mathbf{v}dz=0 \qquad \text{(III-2)}$$

$$\frac{D\mathbf{u}}{Dt}-fv=-\frac{\partial p_a}{\partial x}-g\frac{\partial \eta}{\partial x}-g\frac{\partial}{\partial x}\int_{z}^{\eta}\frac{\rho-\rho_0}{\rho_0}d\xi-\frac{\partial q}{\partial x}+\frac{\partial}{\partial z}(v_v\frac{\partial \mathbf{u}}{\partial z})+v_h\left(\frac{\partial^2\mathbf{u}}{\partial x^2}+\frac{\partial^2\mathbf{u}}{\partial y^2}\right) \qquad \text{(III-3)}$$

$$\frac{D\mathbf{v}}{Dt}+fu=-\frac{\partial p_a}{\partial y}-g\frac{\partial \eta}{\partial y}-g\frac{\partial}{\partial y}\int_{z}^{\eta}\frac{\rho-\rho_0}{\rho_0}d\xi-\frac{\partial q}{\partial y}+\frac{\partial}{\partial z}(v_v\frac{\partial \mathbf{v}}{\partial z})+v_h\left(\frac{\partial^2\mathbf{v}}{\partial x^2}+\frac{\partial^2\mathbf{v}}{\partial y^2}\right) \qquad \text{(III-4)}$$

The transport equation for salt, temperature, and conservative solutes, C, and an equation of state showing that the water density is a function of salinity and temperature are:

$$\frac{\partial C}{\partial t}+\frac{\partial(\mathbf{u}C)}{\partial x}+\frac{\partial(\mathbf{v}C)}{\partial y}+\frac{\partial(\mathbf{w}C)}{\partial z}=\frac{\partial}{\partial z}(K_v\frac{\partial C}{\partial z})+\frac{\partial}{\partial x}\left(Kh\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(Kh\frac{\partial C}{\partial y}\right) \qquad \text{(III-5)}$$

$$\rho=\rho_0\,[1+\alpha s+\beta(T-T_0)^2\,] \qquad \text{(III-6)}$$

where (u, v, w) are (x, y, z) velocity components, η is the free-surface elevation measured from a reference datum, v_v and v_h are vertical and horizontal eddy viscosities, $\frac{D}{Dt}$ is the substantial derivative, ρ and ρ_0 are density and a reference density, p_a is atmospheric pressures, q is non-hydrostatic pressure component, f is the Coriolis parameter, C represents salinity, temperature, or other conservative solutes, K_v and K_h are the vertical and horizontal eddy diffusivities, s is salinity in practical salinity units (psu), T and T_0 are temperature and a reference temperature in ^{0}C, respectively, and constants $\alpha = 7.8 \times 10^{-4}$ and $\beta = 7 \times 10^{-6}$.

The surface wind stress components are computed using the quadratic relationships and the surface boundary conditions are:

$$v_v\frac{\partial u}{\partial z}=\tau_{sx}=C_a\rho_a\,|\,\mathbf{u}_a\,|\,\mathbf{u}_a \qquad \text{(III-7)}$$

$$v_v\frac{\partial v}{\partial z}=\tau_{sy}=C_a\rho_a\,|\,\mathbf{u}_a\,|\,\mathbf{v}_a \qquad \text{(III-8)}$$

where $|\,\mathbf{u}_a\,|=(\mathbf{u}_a^2+\mathbf{v}_a^2)^{1/2}$, u_a and v_a are the horizontal components of wind velocity near the ocean surface, ρ_a is the air density, and C_a is the drag coefficient based on the following equation:

$$C_a=(0.75+0.067\,|\mathbf{u}_a|)\times 10^{-3} \qquad \text{(III-9)}$$

The bottom stress is represented by the Manning's friction relationship:

$$v_v \frac{\partial \mathbf{u}}{\partial z} = \tau_{bx} = \rho \frac{gn^2}{(\Delta z)^{1/3}} (\mathbf{u}^2 + \mathbf{v}^2)^{1/2} \mathbf{u} \qquad \text{(III-10)}$$

$$v_v \frac{\partial \mathbf{v}}{\partial z} = \tau_{by} = \rho \frac{gn^2}{(\Delta z)^{1/3}} (\mathbf{u}^2 + \mathbf{v}^2)^{1/2} \mathbf{v} \qquad \text{(III-11)}$$

where n is the Manning parameter, u and v are bottom layer horizontal velocities, Δz is the bottom layer thickness, and ρ is the water density.

The model is a general three-dimensional model capable of simulating both 2-dimensional (vertical averaged) and 3-dimensional hydrodynamics and transport processes. The model uses a combined finite difference and finite volume scheme. Also, it uses an orthogonal, unstructured grid with mixed triangular and quadrilateral grid cells, which allows better fitting boundaries and local grid refinements to meet the needs of resolving spatial resolution in numerical modeling tasks. Figure III.2 shows an example of an orthogonal grid. The domain is covered by a set of non-overlapping convex polygons. Each side of a polygon is either a boundary line or a side of an adjacent polygon. The z-coordinate is used in the vertical. To relax the CFL condition, the Eulerian-Lagrangian transport scheme is used for treating the convective terms. A semi-implicit finite-difference method of solution was implemented in the model (Casulli, 1999). The terms that affect the numerical stability are treated implicitly, and the remaining terms are treated explicitly, which has proven to be computationally efficient (Cheng and Casulli, 2002). With the use of a Eulerian-Lagrangian transport scheme, the model is not restricted by the CFL condition. Therefore, very fine model grids can be used to represent the model domain without reducing computational efficiency.

III-3. The CE-QUAL-ICM Water Quality Model

The CE-QUAL-ICM water quality model was initially developed as one component of a model package employed to study eutrophication processes in Chesapeake Bay (US Army ERDC, 2000). ICM stands for "integrated compartment model," which is analogous to the finite volume numerical method. The model computes and reports concentrations, mass transport, kinetics transformations, and mass balances. This eutrophication model computes 22 state variables including multiple forms of algae, carbon, nitrogen, phosphorus, silica, and dissolved oxygen. One significant feature of ICM is a diagenetic sediment sub-model, which interactively predicts sediment-water oxygen and nutrient fluxes. Alternatively, these fluxes may be specified based on observations.

CE-QUAL-ICM has been applied to many sites, including Chesapeake Bay, Inland Bays of Delaware, New York Bight, Newark Bay, New York - New Jersey Harbors and

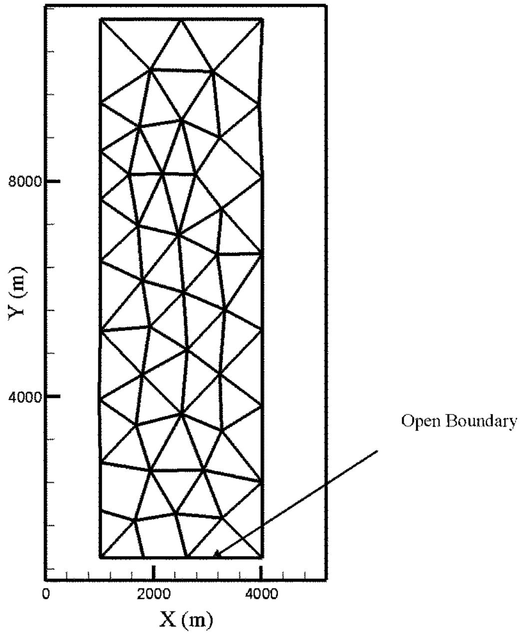


Figure III.2. An example of an orthogonal grid.

Estuaries, Lower Green Bay, Los Angeles - Long Beach Harbors, Cache River wetlands, San Juan Bay and Estuaries, Florida Bay, and Lower St. Johns River.

The foundation of CE-QUAL-ICM is the solution to the three-dimensional mass-conservation equation for a control volume based on the finite volume approach. Transport within the CE-QUAL-ICM (Cerco and Cole, 1995) is based on the integrated compartment method (or box model methodology). The present version of CE-QUAL-ICM transport is a loose extension of the original WASP code (Ambrose et al., 1986). The notion of utilizing the box model concept was retained in order to allow the coupling, via map files, of ICM with various hydrodynamic models. ICM represents "integrated compartment model," which is the finite volume numerical method. The model computes constituent concentrations resulting from transport and transformations in well-mixed cells that can be arranged in arbitrary triangular and quadrilateral configurations. Thus, the model employs an unstructured grid system, which is compatible with UnTRIM.

III-3-1. Linkage between UnTRIM and CE-QUAL-ICM

The foundation of CE-QUAL-ICM is the solution to the three-dimensional mass-conservation equation for a control volume based on the finite volume approach. For each volume and for each state variable, the governing equation that CE-QUAL-ICM solves is:

$$\frac{\delta V_j C_j}{\delta t} = \sum_{k=1}^{n} Q_k C_k + \sum_{k=1}^{n} A_k D_k \frac{\delta C}{\delta x_k} + \sum_{k=1}^{n} S_j \qquad \text{(III-12)}$$

where:
V_j = volume of j^{th} control volume (m^3)
C_j = concentration in j^{th} control volume (mg m^{-3})
t, x = temporal and spatial coordinates
n = number of flow faces attached to j^{th} control volume
Q_k = volumetric flow across flow face k of j^{th} control volume (m^3 sec^{-1})
C_k = concentration in flow across flow face k (mg m^{-3})
A_k = area of flow face k (m^2)
D_k = diffusion coefficient at flow face k (m^2 sec^{-1})
S_j = external loads and kinetic sources and sinks in j^{th} control volume (mg sec^{-1})

The above conservation-of-mass equation is solved in two steps. In the first step, an intermediate value is computed. The intermediate value includes the effects of change in cell volume, longitudinal and lateral transport, and external loading. This horizontal transport is solved using the UPWIND algorithm or the third-order-accurate non-uniform grid QUICKEST algorithm. In the second step, the effects of vertical transport and kinetic transformation are computed. The second-order implicit Crank-Nicolson scheme is used in the vertical direction. The linkage between UnTRIM and CE-QUAL-ICM focuses on the horizontal transport. The details of the horizontal transport methodology and the modifications required for a non-uniform and non-structured grid are presented below.

The original horizontal advection operator in CE-QUAL-ICM was designed to work with structured grid hydrodynamic models such as CH3D (Chapman and Cole, 1992). For a structured grid, grid information is described by rows and columns of cells combined with cell dimensions. The box lengths are directly calculated according to the relationship of rows and columns using a structured grid, and then are used to compute the UPWIND or QUICKEST transport multipliers. Due to prior successful applications of the UPWIND and QUICKEST transport algorithms in CE-QUAL-ICM (Dortch et al., 1991; Chapman and Cole, 1992), a similar approach was adopted for the non-structured version of CE-QUAL-ICM. The vertical transport computation utilizes the same solution, both for structured and unstructured grids.

An essential task of this study was the development of linkage software to provide geometric and hydrodynamic information transferring from UnTRIM output to the CE-QUAL-ICM code and to test the success of the linkage. The software development consisted of three basic parts:

a. Unstructured grid information used by the hydrodynamic model was transferred into CE-QUAL-ICM, including the number of polygons, faces, and the relationship between polygons and faces. The linkage software was developed to map the unstructured grid configuration and geometry information into several files that could be interpreted by the CE-QUAL-ICM code.

b. Hydrodynamic simulation results required for output and transferred into CE-QUAL-ICM. A postprocessor code of UnTRIM was developed to output the 3-dimensional surface area of each polygon and volume of each polygon only at the beginning of the simulation. The 3-dimensional velocity field, surface water elevation information at each face and the center point of each polygon, and vertical diffusivity were output at each time step.
c. CE-QUAL-ICM was modified to accept the UnTRIM linkage information, especially in the input program and transport calculation.

The mapping of grid information between UnTRIM and CE-QUAL-ICM, and the transfer of information between these two models, are described in more detail in Li (2006).

III-3-2. Dissolved oxygen process

(1) Effects of algae in water column on dissolved oxygen

Algae produce oxygen during photosynthesis and consume oxygen through respiration. The quantity produced during photosynthesis depends on the form of nitrogen taken up. Since oxygen is released in the reduction of nitrate (NO_3), more oxygen is produced, per unit of carbon fixed, when NO_3 is the algal nitrogen source than when ammonia NH_4 is the source. When NH_4 is the nitrogen source, one mole of oxygen is produced per mole carbon dioxide fixed. When NO_3 is the nitrogen source, 1.3 moles oxygen are produced per mole carbon dioxide fixed. The equation that describes the effect of algae photosynthesis on DO in the model is:

$$\frac{\delta DO}{\delta t} = \sum_x \left(\left(1.3 - 0.3 PN_x\right) P_x \right) \mathrm{AOCR} \cdot \mathrm{B_x} \qquad \text{(III-13)}$$

where:

PN_x = algal group x preference for ammonium

P_x = production rate of algal group x (day^{-1})

AOCR = DO-to-carbon ratio in respiration (2.67 g O_2 per g C)

B_x = algal biomass (g C m^{-3})

As employed here, basal metabolism is the sum of all internal processes that decrease algal biomass. A portion of the metabolism is respiration and may be viewed as a reversal of production. In respiration, carbon and nutrients are returned to the environment accompanied by the consumption of DO. Respiration cannot proceed in the absence of DO. Basal metabolism cannot decrease in proportion to oxygen availability. Formulation of this process is described as:

$$\frac{\delta DO}{\delta t} = \sum_x \left(-\frac{DO}{KHR_x + DO} BM_x \right) AOCR \cdot B_x \qquad \text{(III-14)}$$

where:

KHR_x = half-saturation constant of DO for algal DOC exudation (g O_2 m^{-3})
BM_x = basal metabolism rates for algal group x (day^{-1})

(2) Effects of nitrification on dissolved oxygen

Nitrification is a process mediated by specialized groups of autotrophic bacteria that obtain energy through the oxidation of ammonia to nitrite and oxidation of nitrite to nitrate. A simplified expression for complete nitrification is:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^{2+} \qquad \text{(III-15)}$$

The equation indicates that two moles of oxygen are required to nitrify one mole of ammonia into nitrate. The simplified equation is not strictly true, however. Cell synthesis by nitrifying bacteria is accomplished by the fixation of carbon dioxide so that less than two moles of oxygen are consumed per mole ammonium utilized (Wezernak and Gannon, 1968). In this study, nitrification is modeled as a function of available ammonium, dissolved oxygen, and temperature:

$$NT = \frac{DO}{KHONT + DO} \frac{NH_4}{KHNNT + NH_4} f(T) \cdot NTM \qquad \text{(III-16)}$$

where:

NT = nitrification rate (gm N m^{-3} day^{-1})
NTM = maximum nitrification rate at optimal temperature (gm N m^{-3} day^{-1})
KHONT = half-saturation constant of DO required for nitrification (gm DO m^{-3})
KHNNT = half-saturation constant of NH_4 required for nitrification (gm N m^{-3})

Therefore, the effect of nitrification on DO is described as follows:

$$\frac{\delta DO}{\delta t} = -AONT \cdot NT \qquad \text{(III-17)}$$

where:

AONT = mass DO consumed per mass ammonia nitrified (4.33 gm DO gm^{-1} N)

(3) Effects of surface reaeration on dissolved oxygen

Reaeration occurs only in the model surface cells. The effect of reaeration is:

$$\frac{\delta DO}{\delta t} = \frac{K_R}{\Delta z_s}(DO_S - DO) \quad \text{(III-18)}$$

where:

K_R = reaeration coefficient (m day $^{-1}$)
Δz_s = model layer thickness (m)
DO_S = dissolved oxygen saturation concentration (gm DO m^{-3})

Saturation dissolved oxygen concentration DO_S is computed (Genet et al., 1974):

$$DO_S = 14.5532 - 0.38217 \cdot T + 0.0054258 \cdot T^2 - \frac{S}{1.80655}\left(0.1665 - 5.866 \cdot 10^{-3} \cdot T + 9.796 \cdot 10^{-5} \cdot T^2\right) \quad \text{(III-19)}$$

where:

S = salinity (ppt)

(4) Effects of Chemical Oxygen Demand on dissolved oxygen

In the present model, chemical oxygen demand represents the reduced materials that can be oxidized through inorganic means. The kinetic equation showing the effect of chemical oxygen demand is:

$$\frac{\delta DO}{\delta t} = -\frac{DO}{KHO_{COD} + DO} K_{COD} \cdot COD \quad \text{(III-20)}$$

where:

COD = chemical oxygen demand concentrations (g O_2-equivalents m^{-3})
KHO_{COD} = half-saturation constant of DO for oxidation of COD (g O_2 m^{-3})
K_{COD} = oxidation rate of COD (day^{-1})

$$K_{COD} = K_{CD} \cdot \exp\left(KT_{COD}[T - TR_{COD}]\right) \quad \text{(III-21)}$$

where:

K_{CD} = oxidation rate of COD at reference temperature TR_{COD} (day^{-1})

KT_{COD} = effect of temperature on oxidation of COD (°C^{-1})
T = water temperature (°C)
TR_{COD} = reference temperature for oxidation of COD (°C).

Overall, the internal sources and sinks of dissolved oxygen include algal photosynthesis and respiration, atmospheric reaeration (surface cells only), heterotrophic respiration, nitrification, and oxidation of COD. The complete kinetic equation showing sediment oxygen demand (bottom cells only) is:

$$\frac{\delta DO}{\delta t} = \sum_x \left((1.3 - 0.3 \cdot PN_x)P_x - \frac{DO}{KHR_x + DO} BM_x \right) AOCR \cdot B_x$$
$$+ \lambda_1 \frac{K_R}{\Delta z_S}(DO_S - DO) - \frac{DO}{KHO_{DOC} + DO} AOCR \cdot K_{DOC} \cdot DOC \qquad \text{(III-22)}$$
$$- AONT \cdot NIT - \frac{DO}{KHO_{COD} + DO} K_{COD} \cdot COD + \lambda_2 \frac{SOD}{\Delta z}$$

III-3-3. Model Phytoplankton Kinetics

There are three functional groups for algae: cyanobacteria, diatoms, and green algae. This grouping is based upon the distinctive characteristics of each class and upon the significant roles these characteristics play in the ecosystem. Cyanobacteria are characterized by their bloom-forming characteristics in freshwater. They are characterized as having small settling velocity and are subject to low predation pressure. Diatoms are large phytoplankton that usually produces the spring bloom in the saline water. Settling velocity of diatoms is relatively large, so the diatoms settling into sediment may be a significant source of carbon for sediment oxygen demand. Diatoms are also distinguished by their requirement of silica as a nutrient. The green algae represent the mixture that characterizes blooming in saline waters during summer and autumn, and are subject to relatively high grazing pressure.

Equations governing the three algal groups are similar. Differences among groups are expressed through the magnitudes of parameters in the equations. Generic equations are presented below, except when group-specific relationships are required. Algal sources and sinks in the conservation equation include production, metabolism, predation, and settling. In the following equations, a subscript, **x**, is used to denote three algal groups: **c** for cyanobacteria, **d** for diatoms, and **g** for green algae. The internal sources and sinks included are growth (production), basal metabolism (respiration and exudation), predation, and settling. The kinetic equations for algae are:

$$\frac{\delta B_x}{\delta t} = (P_x - BM_x - PR_x)B_x - WS_x \frac{\delta B_x}{\delta z} \qquad \text{(III-23)}$$

where:

B_x = algal biomass, expressed as carbon (g C m^{-3})
P_x = growth (production) rates of algae (day^{-1})
BM_x = basal metabolism rates of algae (day^{-1})
PR_x = predation rates of algae (day^{-1})
WS_x = algal settling velocity (m day^{-1})
z = vertical coordinate

(1) Growth (Production)

Algal growth rate depends on nutrient availability, ambient light, and temperature. The effects of these processes are considered to be multiplicative as follows:

$$P_x = PM_x \cdot f(N) \cdot f(I) \cdot f(T) \qquad \text{(III-24)}$$

where:

PM_x = maximum production rate under optimal conditions (day^{-1})
f(N) = effect of sub-optimal nutrient
f(I) = effect of light intensity
f(T) = effect of temperature

(2) Effect of nutrient on growth

Liebig's "law of the minimum" (Odum, 1971) is used, so that nutrient limitation is determined by the single most limiting nutrient:

$$f(N) = \text{minimium}\left\{\frac{NH_4 + NO_3}{KHN_x + NH_4 + NO_3}, \frac{PO_{4d}}{KHP_x + PO_{4d}}, \frac{SAd}{KHS_d + SAd}\right\} \qquad \text{(III-25)}$$

where:

NH_4, NO_3 = ammonium and nitrate nitrogen concentrations, respectively (g N m^{-3})
PO_4d = dissolved phosphate concentration (g P m^{-3})
SAd = dissolved silica concentration (g Si m^{-3})
KHN_x = half-saturation constant for algal nitrogen uptake (g N m^{-3})
KHP_x = half-saturation constant for algal phosphorus uptake (g P m^{-3})
KHS_d = half-saturation constant for silica uptake by diatoms (g Si m^{-3})

(3) Effects of light on growth

The influence of light on phytoplankton production is represented by a chlorophyll-specific production equation (Jassby and Platt, 1976):

$$P^B = P^B m \frac{I}{\sqrt{I^2 + IK^2}} \qquad \text{(III-26)}$$

where:

P^B = photosynthetic rate (g C g^{-1} Chl d^{-1})
$P^B m$ = maximum photosynthetic rate (g C g^{-1} Chl d^{-1})
I = irradiance (E m^{-2} d^{-1})

Parameter Ik is defined as the irradiance at which the initial slope of the production vs. irradiance relationship intersects the value of $P^B m$:

$$IK = \frac{P^B m}{\alpha} \qquad \text{(III-27)}$$

where:

α = initial slope of production vs. irradiance relationship (g C g^{-1} Chl (E $m^{-2})^{-1}$)

Chlorophyll-specific production rate is readily converted to carbon-specific growth rate, through division by the carbon-to-chlorophyll ratio:

$$G = \frac{P^B}{CChl} \qquad \text{(III-28)}$$

where:

CChl = carbon-to-chlorophyll ratio (g C g^{-1} chlorophyll-a)

(4) Effect of temperature on growth

The effect of temperature on algal production is represented by a function similar to a Gaussian probability curve:

$$\begin{aligned} f(T) &= \exp\left(-KTG1_x\,[T - TM_x]^2\right) \quad \text{when } T \le TM_x \\ &= \exp\left(-KTG2_x\,[TM_x - T]^2\right) \quad \text{when } T > TM_x \end{aligned} \qquad \text{(III-29)}$$

where:

TM_x = optimal temperature for algal growth (°C)
$KTG1_x$ = effect of temperature below TM_x on algal growth (°C^{-2})
$KTG2_x$ = effect of temperature above TM_x on algal growth (°C^{-2})

(5) Constructing the photosynthesis vs. irradiance curve

A production versus irradiance relationship is constructed for each model cell at each time step. First, the maximum photosynthetic rate under ambient temperature and nutrient concentrations is determined:

$$P^Bm(N,T) = P^Bm * f(T) * f(N) \qquad \text{(III-30)}$$

where:

$P^Bm(N,T)$ = maximum photosynthetic rate under ambient temperature and nutrient concentrations ($g\ C\ g^{-1}\ Chl\ d^{-1}$)

The single most limiting nutrient is employed in determining the nutrient limitation. Next, parameter Ik is derived from Equation III-27. Finally, the production vs. irradiance relationship is constructed using P^Bm (N,T) and Ik.

(6) Water surface irradiance

Irradiance at the water surface is evaluated at each model time step. Instantaneous irradiance is computed by fitting a sine function to daily total irradiance:

$$I_o = \frac{I_T}{FD}\frac{\pi}{2}\sin\left(\pi\frac{DSSR}{FD}\right) \qquad \text{(III-31)}$$

where:

I_o = irradiance at water surface ($E\ m^{-2}\ d^{-1}$)

IT = daily total irradiance (E m-1)
FD = fractional daylength ($0 < FD < 1$)
DSSR = time since sunrise (d)

I_o is evaluated only during the interval:

$$\frac{1-FD}{2} \leq DSM \leq \frac{1+FD}{2} \qquad \text{(III-32)}$$

where:

DSM = time since midnight (d)

Outside the specified interval, I_o is set to zero.

Irradiance declines exponentially with depth below the surface. The diffuse attenuation coefficient, K_e, is computed as a function of background extinction and concentrations of chlorophyll-a and total suspended solids.

(7) The light attenuation model

The water quality model requires daily solar radiation intensity and fractional day length, in order to simulate the algal growth. The light attenuation model also requires input of the light attenuation coefficient. It is assumed that the light extinction coefficient consists of three parts: background extinction, the light extinction due to suspended solids, and light extinction due to algae:

$$Ke = a_1 + a_2 * TSS + a_3 * CHL \qquad \text{(III-33)}$$

where:

a_1 = background attenuation (m^{-1})
a_2 = attenuation by inorganic suspended solids ($m^2\ g^{-1}$)
a_3 = attenuation by organic suspended solids ($m^2\ g^{-1}$ CHL)
TSS = total suspended solids concentration ($g\ m^{-3}$)
CHL = chlorophyll-a concentration (mg CHL m^{-3})

The "background" attenuation term included attenuation from both water and dissolved organic matter. Individual parameters were determined from Park et al. (1995b). The value for a_1 used in the model is 0.735 m^{-1}, a_2 is 0.018 $m^2\ g^{-1}$, and a_3 is 0.06 $m^2\ mg^{-1}$ CHL.

(8) Basal metabolism

Basal metabolism is commonly considered to be an exponentially increasing function of temperature:

$$BM_x = BMR_x * \exp(KTB_x\ [T - TR_x]) \qquad \text{(III-34)}$$

where:

BMR_x = metabolic rate at reference temperature TR_x (day $^{-1}$)
KTB_x = effect of temperature on metabolism (C^{o-1})
TR_x = reference temperature for metabolism (C°)

(9) Predation

The predation formulation is identical to basal metabolism. The difference in predation and basal metabolism lies in the distribution of the end products of these processes.

$$PR_x = BPR_x \exp (KTB_x (T - TR_x)) \qquad \text{(III-35)}$$

where:

BPR_x = predation rate at TR_x (day $^{-1}$)
KTB_x = effect of temperature on predation ($C^{\circ -1}$)
TR_x = reference temperature for predation (C°)

(10) Settling velocity

The algal settling rate employed in the model represents the total effect of all physiological and behavioral processes that result in the downward transport of phytoplankton. The settling rate employed, from 0.1 m d^{-1} to 0.2 m d^{-1}, was used in the model to optimize the agreement between predicted and observed algae.

(11) Effect of algae on phosphorus

Model phosphorus state variables include total phosphate (dissolved, sorbed, and algal), dissolved organic phosphorus, labile particulate organic phosphorus, and refractory particulate organic phosphorus. The amount of phosphorus incorporated in algal biomass is quantified through a stoichiometric ratio. Thus, total phosphorus in the model is expressed:

$$TotP = PO_4d + PO_4p + \sum_x Apc*Bx + DOP + LPOP + RPOP \qquad \text{(III-36)}$$

where:

TotP = total phosphorus (g P m^{-3})
PO_4d = dissolved phosphate (g P m^{-3})
PO_4p = particulate inorganic phosphate (g P m^{-3})
Apc = algal phosphorus-to-carbon ratio (g P g^{-1} C)
DOP = dissolved organic phosphorus (g P m^{-3})
LPOP = labile particulate organic phosphorus (g P m^{-3})
RPOP = refractory particulate organic phosphorus (g P m^{-3})

Algae take up dissolved phosphate during production and release dissolved phosphate and organic phosphorus through respiration. The fate of phosphorus released by respiration is determined by empirical distribution coefficients. The fate of algal phosphorus incorporated by zooplankton and lost through zooplankton mortality is determined by a second set of distribution parameters.

(12) Effect of algae on nitrogen

Model nitrogen state variables include ammonium, nitrate + nitrite, dissolved organic nitrogen, labile particulate organic nitrogen, and refractory particulate organic nitrogen. The amount of nitrogen incorporated in algal biomass is quantified through a stoichiometric ratio. Thus, total nitrogen in the model is expressed:

$$TotN = NH_4 + NO_3 + \sum_x Anc*Bx + DON + LPON + RPON \qquad \text{(III-37)}$$

where:

$TotN$ = total nitrogen (g N m^{-3})
NH_4 = ammonium (g N m^{-3})
NO_3 = nitrate + nitrite (g N m^{-3})
Anc = algal nitrogen-to-carbon ratio (g N g^{-1} C)
DON = dissolved organic nitrogen (g N m^{-3})
LPON = labile particulate organic nitrogen (g N m^{-3})
RPON = refractory particulate organic nitrogen (g N m^{-3})

Algae take up ammonium and nitrate + nitrite during production and release ammonium and organic nitrogen through respiration. Nitrate + nitrite is internally reduced to ammonium before synthesis into biomass occurs (Parsons et al., 1984). Trace concentrations of ammonium inhibit nitrate reduction so that, in the presence of multiple nitrogenous nutrients, ammonium is utilized first. The "preference" of algae for ammonium is expressed by an empirical function (Thomann and Fitzpatrick, 1982):

$$\begin{aligned} PN &= NH_4 * \frac{NO_x}{(KHn + NH_4)*(KHn + NO_x)} \\ &\quad + NH_4 * \frac{KHn}{(NH_4 + NO_x)*(KHn + NO_x)} \end{aligned} \qquad \text{(III-38)}$$

where:

PN = algal preference for ammonium uptake ($0 < Pn < 1$)
KHn = half saturation concentration for algal nitrogen uptake (g N m^{-3})

When nitrate + nitrite is absent, the preference for ammonium is unity. When ammonium is absent, the preference is zero.

(13) Effect of algae on silica

The model incorporates two siliceous state variables: dissolved silica and particulate biogenic silica. The amount of silica incorporated in algal biomass is quantified through a stoichiometric ratio. Thus, total silica in the model is expressed:

$$TotSi = Dsil + Asc * Bx + PBS \quad \text{(III-39)}$$

where:

TotSi = total silica (g Si m^{-3})
Dsil = dissolved silica (g Si m^{-3})
Asc = algal silica-to-carbon ratio (g Si g^{-1} C)
PBS = particulate biogenic silica (g Si m^{-3})

As with the other nutrients, the fate of algal silica released by metabolism and predation is represented by distribution coefficients.

III-3-4. Benthic sediment process

Additionally, a benthic sediment process model developed by DiToro and Fitzpatrick (1993) was incorporated and coupled with CE-QUAL-ICM for the present model application. The model state variables, and resulting fluxes, include dissolved oxygen, ammonium, nitrate-nitrite, and phosphate and the parameters used in this sediment flux model are listed in the Table V.10 of Chapter V.

The sediments in this model are represented by two layers: the upper aerobic layer (Layer 1) and the lower anoxic layer (Layer 2). The sediment process model is coupled with the water column eutrophication model through depositional and sediment fluxes. First, the sediment model is driven by net settling of particulate organic matter from the overlying water column to the sediments (depositional flux). Then, the mineralization of particulate organic matter in the lower anoxic sediment layer produces soluble intermediates, which are quantified as diagenesis fluxes. The intermediates react in the upper oxic and lower anoxic layers, and portions are returned to the overlying water column as sediment fluxes. Computation of sediment fluxes requires mass-balance equations for ammonium, nitrate, phosphate, sulfide/methane, and available silica. Mass-balance equations are solved for these variables for both the upper and lower layers. Complete model documentation of the sediment flux model can be found in DiToro and Fitzpatrick (1993).

It should be noted that, due to the critical nature of impacts to Lynnhaven water clarity from total suspended solids (TSS), a decision was made to add to the project scope of work the development of a sediment transport model capable of fully simulating the processes of erosion, deposition, and sediment resuspension. This sediment transport model is described in the next section.

III-4. Description of the sediment transport model

The model utilized in this study is principally based on that of Sanford (2008). As the mud percentage of the bottom sediments in the Lynnhaven basin is larger than 10% in most parts of the Basin and the bottom sediments are mainly composed of silty clay, the formulae of cohesive sediment erosion and deposition were adopted, which are described in the following. The spatial distribution of the sand percentage, and the percentage of silt and clay in the bottom sediment was obtained by grain size analysis of the sediment samples in the basin (Figure III.3). It can be seen that in the inlet and the main channels of the Western and Eastern Branches, sand takes up most part of the sediment. Sand also dominates in the shallow area along the shoreline, mostly induced by shoreline erosion. For most of the area in the basin, sand percentage is less than 90%.

In this study, only silt and clay were simulated. To account for the sediment consolidation, the method of Sanford (2008) for adjusting the bottom critical shear stress was adopted. It assumes that there exists a vertical profile of the equilibrium critical shear stress through the sediment bed, and the actual critical shear stress adapts to the equilibrium one in a first-order time evolution manner.

$$\frac{\partial \tau_c}{\partial t} = r_c(\tau_{ceq} - \tau_c)H(\tau_{ceq} - \tau_c) + r_s(\tau_{ceq} - \tau_c)H(\tau_c - \tau_{ceq}) \qquad \text{(III-40)}$$

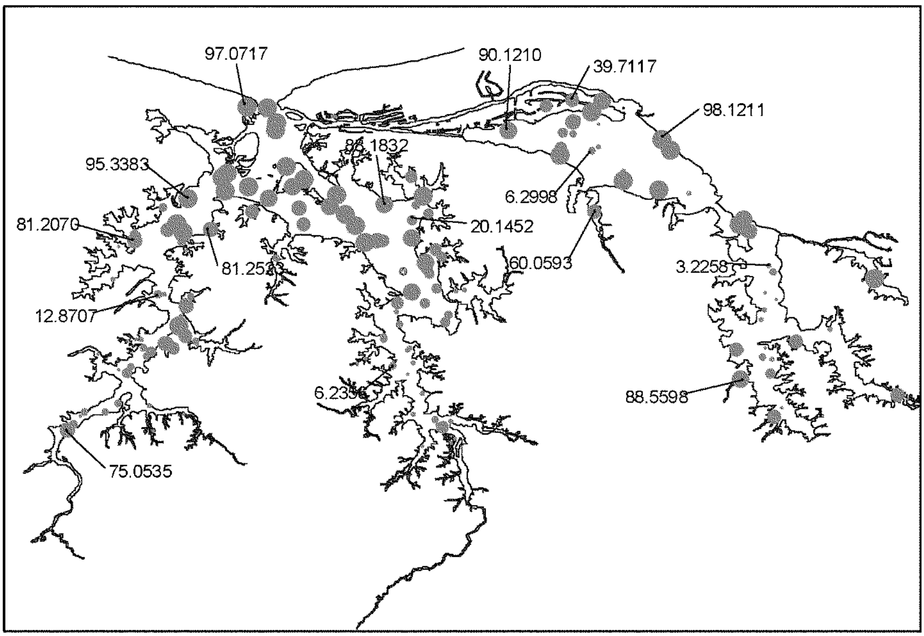


Figure III.3. Sand percentage of the bottom sediment of the Lynnhaven River.

Where τ_c is the instantaneous critical shear stress, τ_{ceq} is the equilibrium critical shear stress, H is the Heaviside step function, defined such that $H = 1$ when its argument is ≥ 0 and $H = 0$ otherwise. In Eq. (III-40), r_c is the first-order consolidation rate and r_s is the first-order swelling rate, which is much smaller than r_c. In this study r_c was set as $\frac{1}{3}$ per day and $r_s = 0.01 r_c$, following Sanford (2008).

The erosion rate is

$$E = M\left(\frac{\tau_b(t)}{\tau_c} - 1\right) \qquad if(\tau_b > \tau_c)$$
$$E = 0 \qquad if(\tau_b \leq \tau_c) \qquad \text{(III-41)}$$

Where τ_b is the bottom stress, M is an erosion rate parameter, which can be obtained from the observation data, like that in Baltimore Harbor, Maryland, USA (Lin et al., 2003). In this study it was adjusted until the model results agreed with measurements and, thus, the calibrated value of M is 0.0004 g/m^2/s.

In this study, the equilibrium critical shear stress profile was set equal to the critical stress profile obtained by bottom sediment erodibility tests in Lynnhaven basin by Sanford and Suttles.

$$\tau_{ceq} = 0.7006 m^{1.5309} \qquad \text{(III-42)}$$

Where τ_{ceq} is the equilibrium critical shear stress defined at the interface between layers, m is the accumulated sediment mass (kg) within the layers above the interface. The equilibrium critical shear stress at the water-sediment interface was specified spatially varying. The spatial distribution of the water-sediment interface equilibrium critical shear stress was obtained by executing the hydrodynamic model for approximately one month to cover the spring-neap tidal variability, and averaging the modeled bottom stress for every cell. The result of equilibrium critical shear stress distribution at the water-sediment interface is shown in Figure III.4. It can be seen that the shear stress has good correlation with the sand percentage of the bottom sediment, the higher sand percentage, the larger of the shear stress. This is consistent with the findings of Molinaroli et al. (2007) that the sediment sorting was mostly controlled by the tidal hydrodynamics in the Lagoon of Venice, Italy. They obtained a good relationship between the sand percentage of the bottom sediment and the mean tidal velocity.

The equilibrium critical shear stress of water-sediment interface was assigned to the corresponding cells. From Figures III.3 and III.4, the equilibrium critical shear stress of the water-sediment interface for the areas with sand percentages less than 70% was mostly close to 0.03 Pa, which is consistent with the measurement data of Sanford and Suttles. Under the water-sediment interface, a total of 25 bed layers were defined. At each layer of the first 20 layers a sediment mass of 0.5 kg/m^2 was specified, whereas for the last 5 layers sediment masses were given as 5.0, 25, 50, 75 and $100 kg/m^2$, respectively. The equilibrium critical shear stress for each layer was specified as the larger of water-sediment interface one and that derived from Eq. (III-42).

At each time step, the bed layers were adjusted by adding or removing layers to account for the deposition or erosion in the bed based on Sanford (2008). With newly deposited sediment at first layer of the bottom, the critical shear stress at the water-sediment interface was decreased as demonstrated by Lin et al. (2003). When the sediment was eroded from the layer, the critical shear stress was increased as illustrated from Eq. (III-41). After the above adjustment, the critical shear stresses were relaxed to the equilibrium ones based on Eq. (III-40).

The deposition rate of cohesive sediment was calculated as

$$D = \begin{cases} w_s C_b \dfrac{\tau_{dc} - \tau_b}{\tau_{dc}} & \text{for } \tau_{dc} > \tau_b \\ 0 & \tau_{dc} \le \tau_b \end{cases} \qquad \text{(III-43)}$$

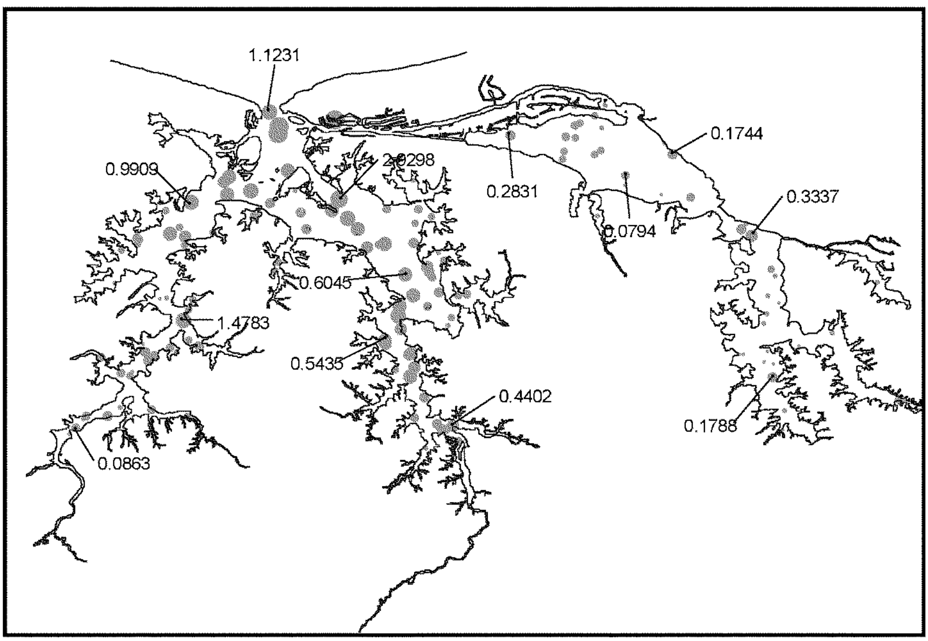


Figure III.4. Average bottom shear stress obtained by one month of hydrodynamic simulation.

Where τ_{dc} is the critical shear stress for deposition, which was set as 0.03 Pa in this study. The existence of a critical shear stress for deposition is debatable, a value of 0.035 Pa has been utilized in Lin and Kuo's (2003) study, and a continuous settling concept was adopted by Sanford (2008).

To account for the flocculation, the cohesive sediment's settling velocity dependence on concentration was utilized, which was obtained by Kwon (2005) through measurement in the York River as follows:

$$w_s = 3.5 * 10^{-5} C^{0.375} \quad \text{(III-44)}$$

where w_s is in units of m/s and C is in units of g m^{-3}.

The calibration of the Lynnhaven River sediment transport model is presented in Section V-3 and its validation is presented in Section VI-3.

III-5. Description of the watershed model for the Lynnhaven River Basin

As VIMS has developed the hydrodynamic and water quality models for the Lynnhaven River receiving waters, URS Corporation of Virginia Beach has developed a watershed model for the Lynnhaven River Basin. The watershed model used by URS is HSPF (Hydrological Simulation Program – FORTRAN), version 12 (URS Technical Memorandum, Hydrologic Concepts and Parameter Development, 2006).

The goal of the watershed modeling effort is to provide the freshwater discharge and nutrient and sediment loadings from the watershed at high spatial and temporal resolutions. The Lynnhaven River Basin, consisting of 7 sub-basins, has been delineated into 1,079 catchments, ranging in size from approximately 40 acres, as shown in Figure III.5.

The landuse in the Lynnhaven Basin is 40% residential and 35% composed of streets, commercial and office space, and military use. In its watershed model development, URS selected a total of 23 land uses within the Lynnhaven River basin into which zoning codes could then be grouped. URS then assigned to each landuse a directly connected impervious percentage, as shown in Table III.1. Landuse was employed to develop effective impervious area percentages for the nearly 57,000 land parcels within the Lynnhaven Basin.

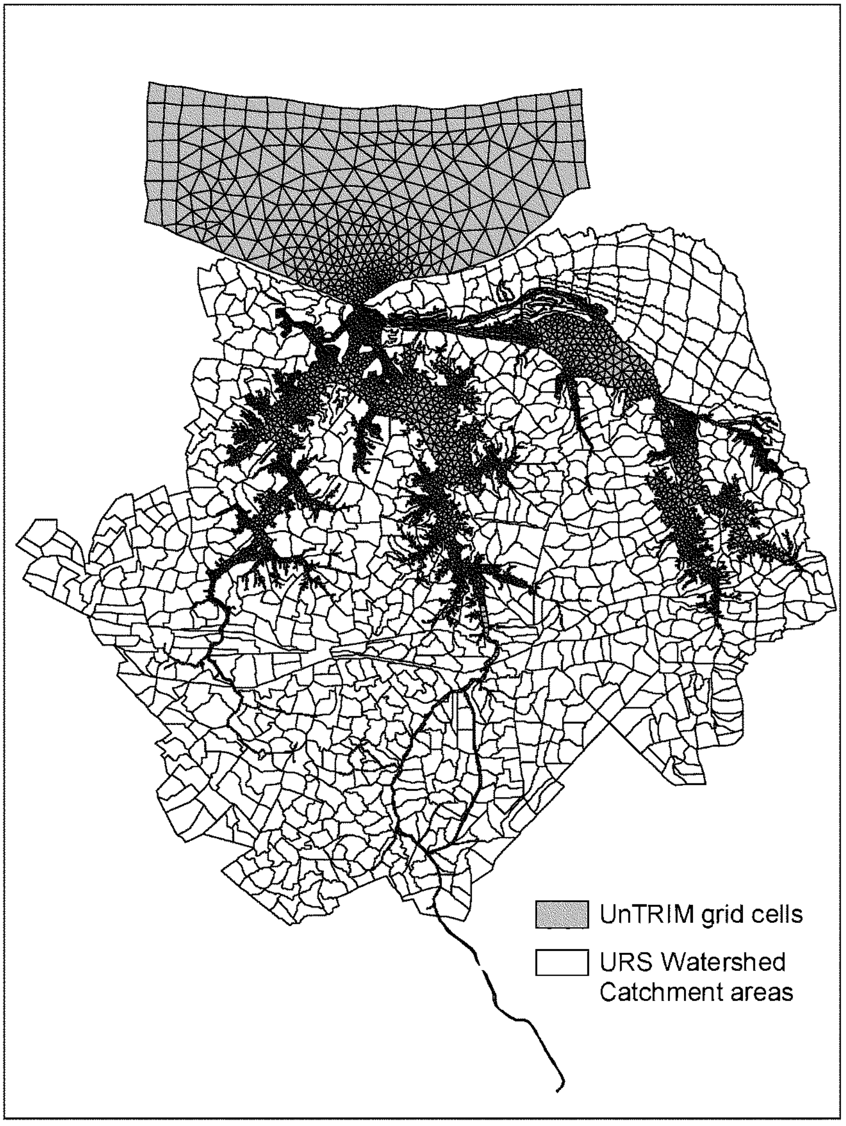


Figure III.5. The 1079 catchment areas delineated by the URS watershed model superimposed on the UnTRIM model grid.

For each of these catchments, the URS model simulates the following 9 constituents:

- biochemical oxygen demand (BOD)
- total dissolved solids (TDS)
- chemical oxygen demand (COD)
- nitrate – nitrite (NO_3)
- total Kjeldahl nitrogen (TKN)
- ammonia (NH3)
- total phosphorus (TP)
- dissolved phosphorus (DP)
- total suspended sediments (TSS)

The URS model was calibrated for by comparing its predictions to monitoring data collected at 5 sites within and/or nearby the Lynnhaven basin (URS, 2007). The calibrated model was then used to provide multi-year datasets of its outputs of hourly nutrient loadings and freshwater discharge to the VIMS models.

Table III.1. Impervious percentages of Lynnhaven Basin Landuse Categories.

Landuse No.	Landuse	Landuse Description	Impervious Percentage
1	AG	Agricultural	15%
2	SFL	Single Family Low Density	16%
3	SFM	Single Family Medium Density	21%
4	SFH	Single Family High Density	24%
5	MFM	Multi-Family Medium Density	37 %
6	MFH	Multi-Family High Density	62%
7	PD	Planned Development	29%
8	O	Office	71%
9	NB	Neighborhood Business	39%
10	B	Business	73%
11	I	Industrial	45%
12	RT	Resort Tourist	71%
13	PK	Park	5%
14	GC	Golf Course	5%
15	OS	Open Space	0.5%
16	OF	Other facilities	8%
17	SC	School	47%
18	ST	Street	60%
19	CM	Cemetary	5%
20	CH	Church	47%
21	WT	Wetland	100%
22	BMP	Best Management Practice	100%
23	WAT	Water	100%

CHAPTER IV. HISTORICAL DATA AND FIELD OBSERVATION PROGRAM

IV-1. Historical Data

Historical monitoring and survey data collection in the Lynnhaven River have taken place since the late 1950s. Prior to the inception of this project, VIMS made a conscious effort to gather all available hydrodynamic and water quality data recorded from the Lynnhaven River system into a central database. The intended range of parameters included in the database span those needed for the calibration and validation of the hydrodynamic and water quality models. Specifically, these include hydrodynamic parameter data (tides, velocities, salinities, and temperatures) and water quality parameter data (dissolved oxygen, chlorophyll, nutrient concentrations, and sediment-related measurements). Historical data for the Lynnhaven originated from 3 state agencies (Virginia Department of Environmental Quality [VA-DEQ], Virginia Department of Shellfish Sanitation [VA-DSS], and Virginia Institute of Marine Science [VIMS]), 1 federal agency (National Oceanic and Atmospheric Administration [NOAA]), and 1 environmental consulting company (Malcolm Pirnie Engineers). Whereas VIMS, NOAA, and Malcolm Pirnie conducted surveys of the Lynnhaven, most water quality parameter measurements have been provided by the ongoing monitoring programs of VA-DEQ (every other month, 1984 to present) and VA-DSS (monthly, 1986 to present). These data are summarized in Table IV.1.

Table IV.1. Lynnhaven monitoring and survey data collected, by parameter and agency.

Sections	Parameter	Number of Observations by Agency				Total Observations
		DEQ	DSS	VIMS	M. PIRNIE	
IIA	Tides					5953
IIB	Velocity					
IIC	Salinity	2924	2269	511	200	5904
IID	Temperature	2648	1275	475	200	4598
IIIA	Dissolved Oxygen	5208	-	527	400	6135
IIIB	Chlorophyll a	149	-	511	200	860
IIIC	BOD5	2133	-	135	200	2468
IIID	Total Organic Carbon	1863	-	-	-	1863
IIIE	TKN	1954	-	459	200	2613
IIIF	Ammonia	2351	-	-	-	2351
IIIG	Nitrite	2645	-	-	-	2645
IIIH	Nitrate	2224	-	-	-	2224
IIII	Total Phosphorus	1682	-	459	200	2341
IIIJ	Ortho Phosphorus	1158	-	-	-	1158
IIIK	Dissolved Silica	315	-	36	-	351
IIIL	TSS	2072	-	16	200	2288
IIIM	Volatile Susp. Solids	2076	-	-	-	2076
IIIN	Volatile Solids	1771	-	-	-	1771
IIIO	Turbidity	1061	-	-	-	1061
IIIP	Secchi depths	-	1142	459	200	1801
IIIQ	Fecal Coliform	1010	17,725	459	200	19,394
TOTAL		35,097	22,411	4047	2200	69,855

Spatial plots of long-term averages of hydrodynamic and water quality parameters can often reveal important characteristics of a waterbody such as the Lynnhaven. It can be seen from the long-term averages for salinity at DEQ stations, shown in Figure IV.1, that much larger salinity gradients exist in the Western and Eastern Branches than in the Broad Bay / Linkhorn Bay Branch. This is because the freshwater inputs from the former branches are larger than that of the later. Spatial plots of water quality parameters can be used to highlight the spatial gradient of the water quality parameters as well as identify the regions of concerns, such as the DEQ stations at Thalia Creek and London Bridge, as shown in Figure IV.2. One of the major characteristics revealed was that the concentration of all water quality variables were higher at the upstream of each branch and decreased moving downstream toward the Inlet.

The availability of long-term monitoring data additionally allows for time series analysis and, in the case of long-term trend, a simple linear trend analysis was performed for all parameters. Examples of this include the long-term decrease of dissolved oxygen at the Thalia Creek Station shown in Figure IV.3a and the decrease of total organic carbon at the Broad Bay Station BBY002.88 shown in Figure IV.3b. Table IV.2 enumerates the long-term trends of all water quality parameters measured at each Lynnhaven DEQ station as either increasing (I) or decreasing (D).

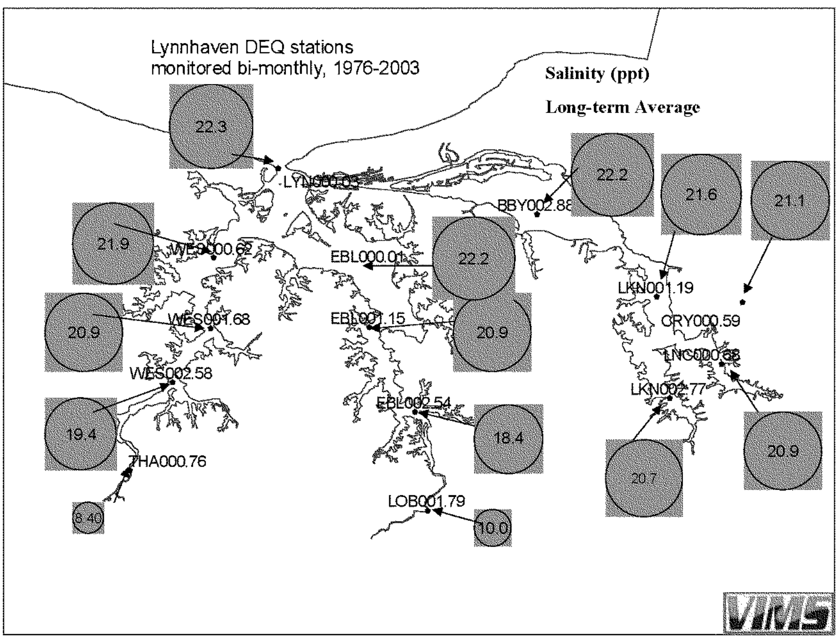


Figure IV.1. Long-term average salinity based on Lynnhaven DEQ observations.

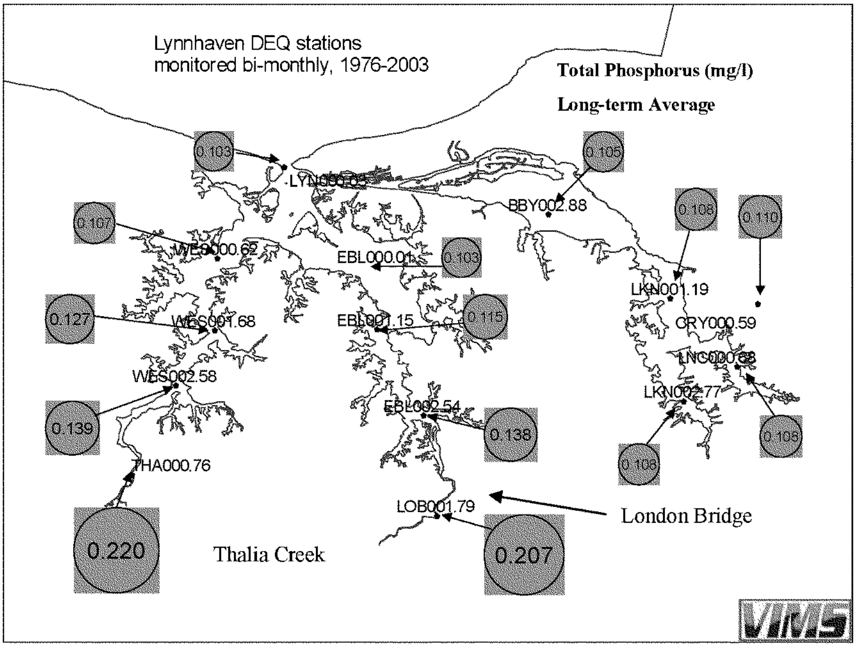


Figure IV.2. Long-term average total phosphorus based on Lynnhaven DEQ observations.

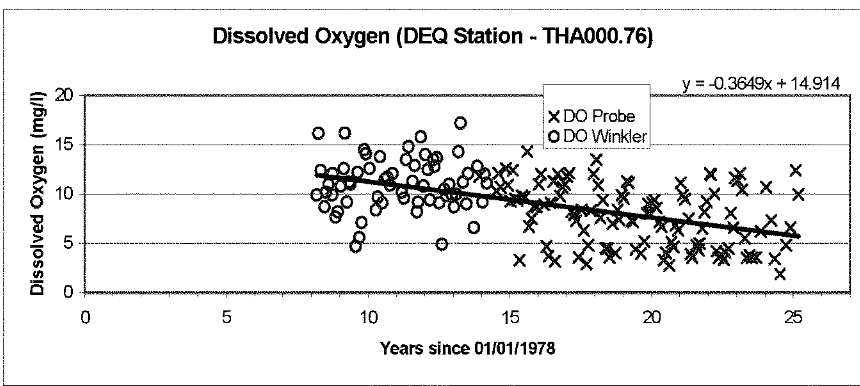


Figure IV.3a. Long-term trend of observed dissolved oxygen at DEQ Station THA000.76.

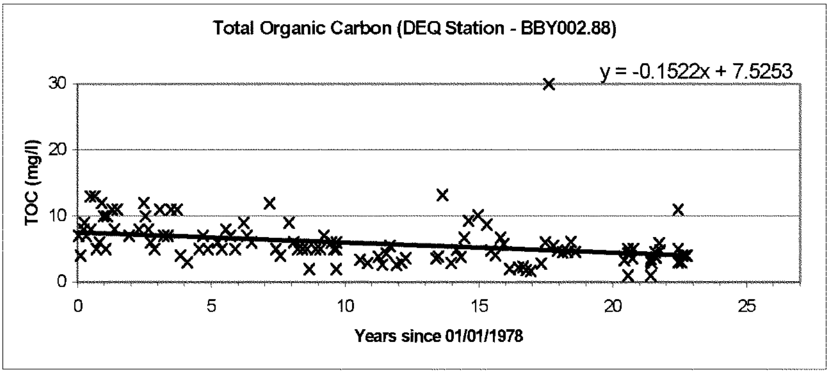


Figure IV.3b. Long-term trend of observed TOC at DEQ Station BBY002.88.

Table IV.2. Lynnhaven DEQ monitoring long-term trends.

DEQ Station	THA000.76	WES002.58	WES001.68	WES000.62	LYN000.03	EBL000.01	EBL001.15	EBL002.54	LOB001.79	BBY002.88	LNK001.19	LNK002.77	LNC000.68	CRY000.59
Parameter														
Salinity	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Temperature	D	I	I	I	I	I	I	I	D	I	I	I	I	I
Dissolved Oxygen	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Chlorophyll a														
BOD5	D	D	I	I	D	I	D	D	D	D	I	I	D	D
TOC	D	D	D	D	D	D	D	D	D	D	D	D	D	D
TKN	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Ammonia	Regression not reported - interference from detection limit change													
Nitrite	Regression not reported - interference from detection limit change													
Nitrate	Regression not reported - interference from detection limit change													
Total Phosphorus	Regression not reported - interference from detection limit change													
Ortho Phosphorus	D	D	D	I	I	I	I	I	D	D	D	D	D	D
Dissolved Silica	D	D	D	D	D	D	D	D	D	D	D	D	D	D
TSS	D	D	D	D	D	D	D	D	D	D	D	D	D	D
VSS	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Volatile Solids	I	D	D	D	D	D	D	D	I	D	D	D	D	D
Turbidity	D	D	I	D	I	D	D	D	I	I	I	I	D	D

"I" denotes a long-term increasing trend and "D" denotes a long-term decreasing trend

IV-2. Project-specific field measurements

For the data to be useful for the hydrodynamic and water quality modeling, project-specific measurements are required. There are five field data collections were designed and conducted during the course of the project. They are described in the following sections: (1) the hydrodynamic survey in Section IV-2-1, (2) seasonal sediment flux measurements in Section IV-2-2, (3) sediment critical shear stress measurements in Section IV-2-3, (4) High spatial resolution dataflow surveys in Section IV-2-4, and (5) high-frequency time series measurements in Section IV-2-5.

IV-2-1. VIMS hydrodynamic survey

A unique VIMS hydrodynamic survey was conducted from November 1, 2005 to December 1, 2005. The purpose of the survey was to obtain a synoptic dataset of tide and representative currents for validation of the hydrodynamic model. In order that the data can be analyzed using harmonic analysis, the survey was designed to be at the least on the order of 30 days (at least 697 hours).

There are multiple measurements that were conducted depending on the site characteristics. Instruments were deployed as follows: 1) a tide gauge recording water surface elevations at 6-minute intervals at the Virginia Pilot's Station, 2) an Acoustic Doppler Current Profiler (ADCP) outside the Inlet recording current magnitude and direction at 20-minute intervals at each of ten 0.3-m intervals in the vertical, and 3) S4 current meters located at mid-depths in each of the three Lynnhaven Branches recording velocity speed and direction, temperature, and salinity at 30-minute intervals.

The instrument locations are shown in Figure IV.4. Tide measured at the Virginia Pilot's Station (Inlet mouth) showed a 1-hour phase lag from that at the nearby Chesapeake Bay Bridge Tunnel (CBBT) primary station, as well as a drop in amplitude to 36 cm from 38 cm at CBBT (Figure IV.5). The ADCP profiler was used because the channel has a greater depth and potentially different velocities from surface to bottom. The ADP velocity measured results outside the Inlet, as shown in Figure IV.6, and indeed showed a 2-layer circulation with a slight residual in the ebb (north) direction at the surface and in the flood (south) direction at the bottom.

Within the branches, the single S4 current meters were deployed due to their shallow depth. The time series plots show maximum currents on the order of 30 cm/sec, 40 cm/sec, and 80 cm/sec, respectively, for the Western, Eastern, and Broad Bay Branches (Figures IV.7 - IV.9). The larger velocity measured in Broad Bay was because the location of deployment was near Long Creek, where the cross section is much narrower. Otherwise, the range of velocity was typical for the coastal bays in the Chesapeake Bay. Additionally, the impacts of both a heavy rainstorm on salinity (Figures IV.7 and IV.9) and a noteworthy cold front on water temperature (Figures IV.10 and IV.11) are readily observable in this shallow water system.

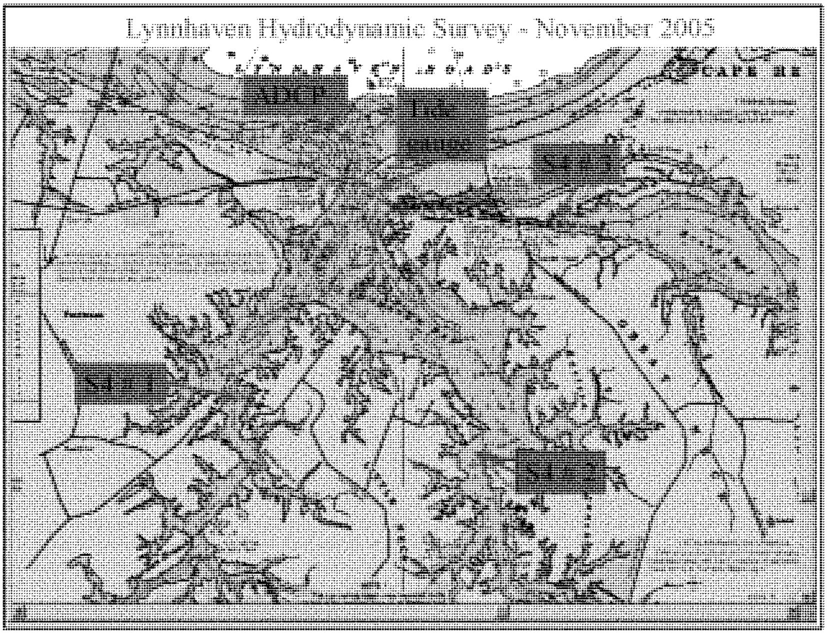


Figure IV.4. Instrument Locations for VIMS Hydrodynamic Survey.

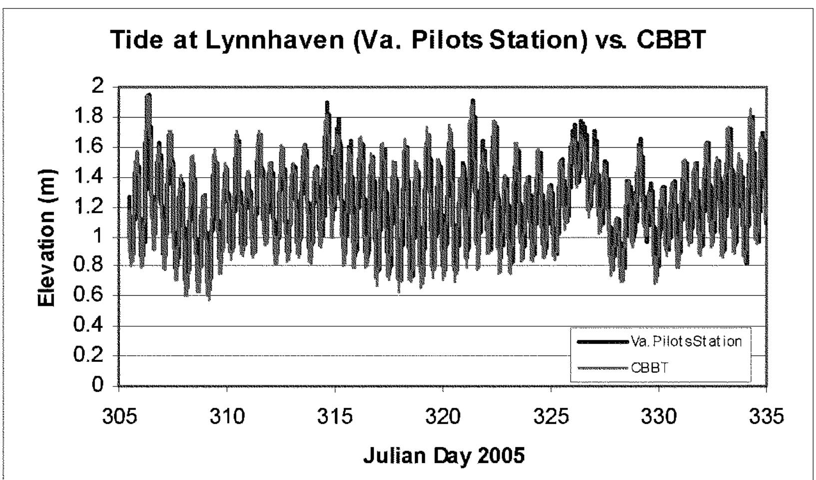


Figure IV.5. Tide at Inlet versus CBBT tide.

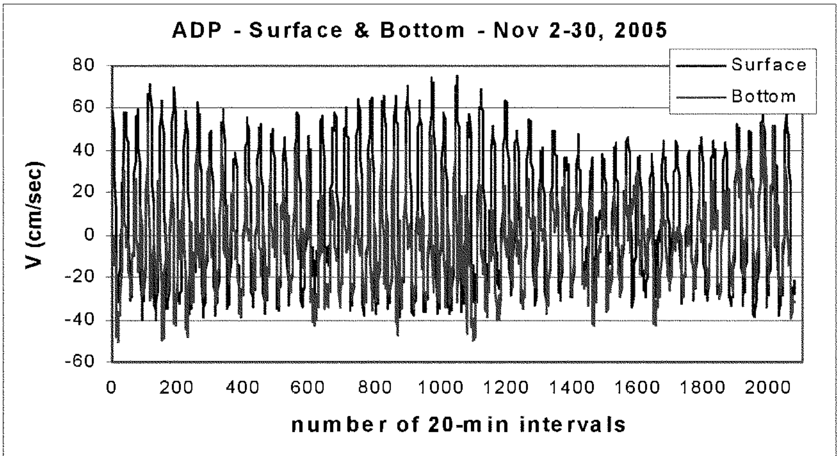


Figure IV.6. ADP velocity outside Inlet.

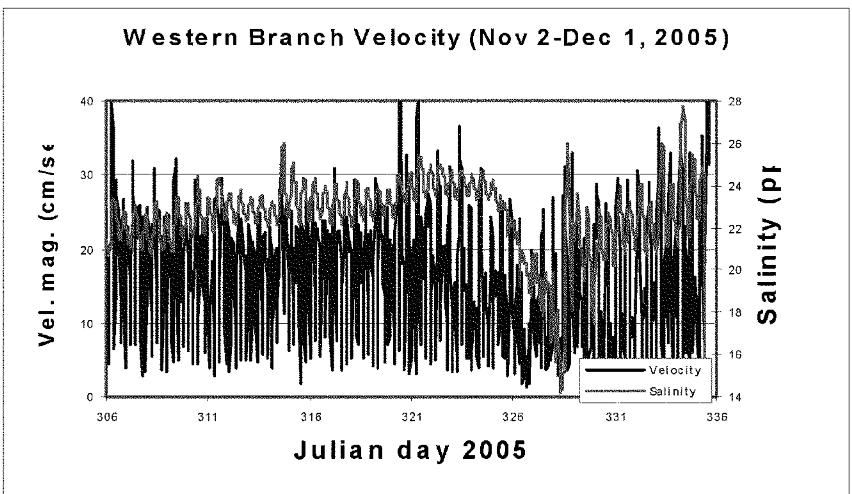


Figure IV.7. Western Branch velocity and salinity.

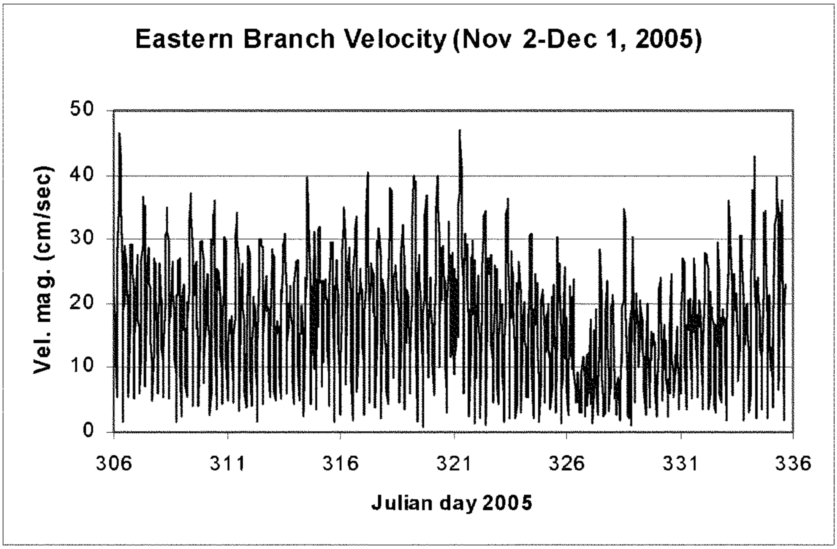


Figure IV.8. Eastern Branch velocity.

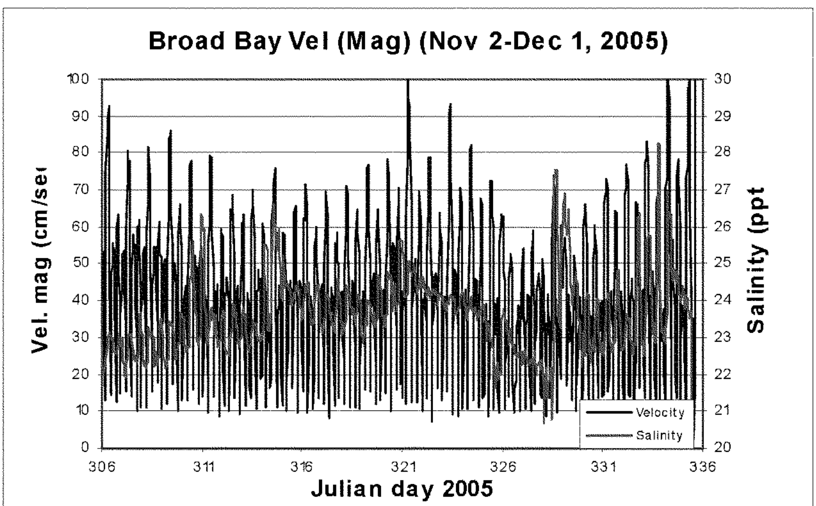


Figure IV.9. Broad Bay velocity and salinity.

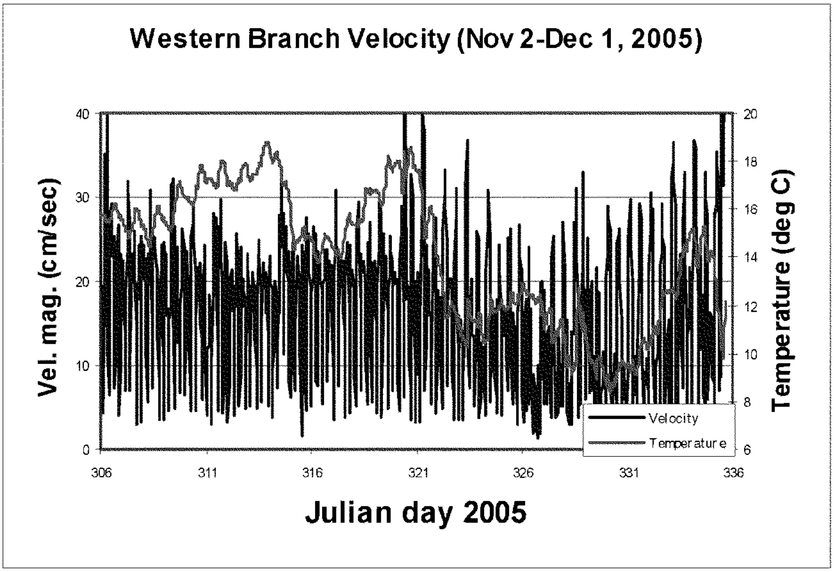


Figure IV.10. Western Branch velocity and temperature.

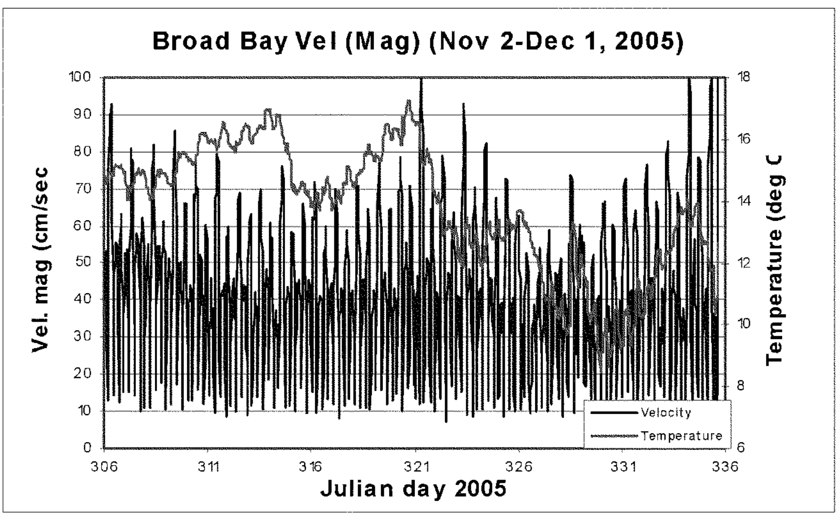


Figure IV.11. Broad Bay velocity and temperature.

IV-2-2. Seasonal sediment flux measurements

Due to the shallowness of the Lynnhaven River, the sediment and water column interact. Fluxes of dissolved oxygen and inorganic nutrients between sediments and the overlying water column were measured seasonally in four selected regions of the Lynnhaven River system: Western Branch, Eastern Branch, the Inlet, and Broad Bay (Figure IV.12). Sites were selected in nearshore, shallow regions of the Lynnhaven so samples would contain actively photosynthesizing benthic microalgae (BMA), which can dominate carbon production in shallow systems, in addition to the microbial community that dominates respiration at all depths. The averaged water depth at the collection sites was about 0.4 meter at mean low water with a tidal range of 1.0 meter. Within each embayment, four sediment cores were taken during each survey. A preliminary site selection and characterization study was conducted in March 2005, with flux studies occurring in April 2005 (14°C), July 2005 (26°C), November 2005 (15°C), and May 2006 (22°C).

In the field, four sediment cores (clear acrylic, 20-cm sediment depth, 20-cm overlying water, 13.3 cm diameter) were collected from each embayment with minimal disturbance. For each core, a second small core was collected for measurement of sediment bulk density, organic content, and BMA biomass measured as chlorophyll-*a* in the top 1 and 3 cm of sediment. Ambient water was collected at each site for use during core incubations.

All cores were placed in a temperature and light-controlled environmental chamber at VIMS, submerged (without lids) in large mesocosms with site-specific water (Figure IV.13), and gently bubbled with air overnight to allow cores to acclimate to the experimental chamber. Two "water blank" cores per site were filled with water only to serve as controls to correct for processes occurring in the water overlying each sediment core. Temperature in the chamber was set to the average field temperature to ensure comparability.

The following morning, cores were capped with clear lids fit with magnetic stir-bars to gently circulate the water within the cores, controlled by a central motor in each mesocosm (Figure IV.13). Each lid was equipped with two ports, one for sampling and a second to allow replacement water to flow in from a reservoir with site-specific water. Care was taken to exclude bubbles while capping the cores.

Cores were incubated following the general procedure of Anderson et al. (2003), beginning in the dark for 3-4 hours to measure fluxes associated with sediment respiration. Samples were collected hourly for determination of concentrations of dissolved oxygen (DO), ammonium (NH_4^+), nitrate + nitrite (NO_x^-), and phosphate (PO_4^{3-}). Following the last sampling, the lights in the environmental chamber were turned on to approximately saturating levels of irradiance for BMA (417-673 $\mu E\ m^{-2}\ s^{-1}$ at the

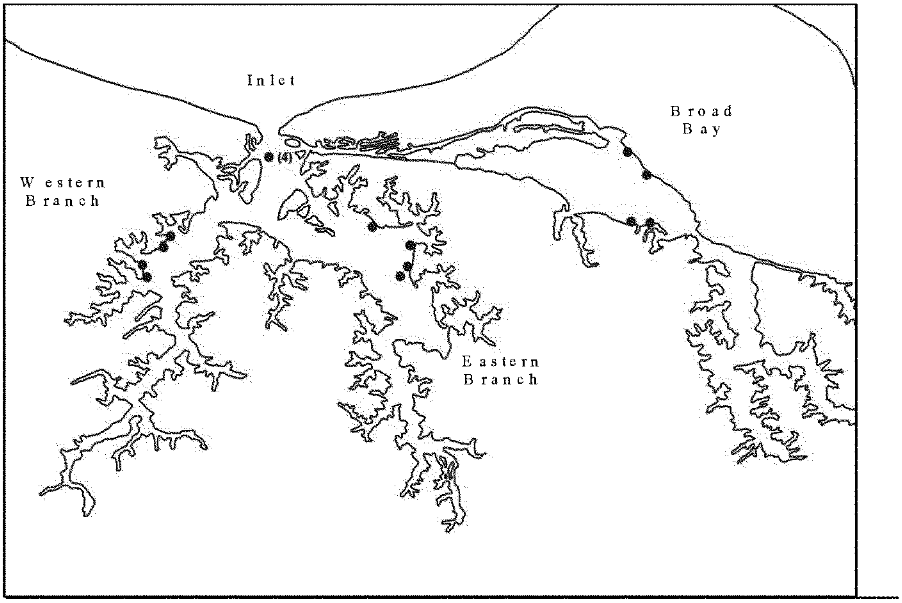


Figure IV.12. Location of core collection sites for sediment flux in the Lynnhaven River. Four cores were collected in close proximity inside the Inlet.

water surface; 165-360 µE m^{-2} s^{-1} at the sediment surface). Cores were allowed to acclimate for 30 minutes after which DO and nutrients were again sampled hourly for 3-4 hours to measure fluxes associated with BMA photosynthesis.

DO and nutrients in each reservoir of replacement water were measured at the beginning, midpoint, and end of each experiment to allow for dilution correction of the water within each core.

Dissolved oxygen and temperature were measured with an Orion galvanic DO sensor. Samples for nutrients were filtered through 0.45 µm filters (Gelman Supor) and frozen (-15°C) until later analysis on a Lachat autoanalyzer. Samples for sediment chlorophyll-*a* and pheophytin concentrations were frozen until extraction with 100% acetone following the methods of Pinckney and Zingmark (1994) as modified by Pinckney and Lee (2008). Concentrations were analyzed on a Shimadzu UV-1601 spectrophotometer and calculated using the equations of Lorenzen (1967). Sediment organic content was determined as the percent weight loss following combustion at 500°C for 5 hours.

Flux rates in the light and dark were computed as the time rate of change (i.e., slope) of concentration, corrected for dilution by reservoir water. To determine fluxes attributable to the sediments only, the average slope from the two water blanks at each site was subtracted from the slope of each sediment core.

Results

BMA biomass as measured by sediment chlorophyll-a concentration was higher at the Broad Bay and Inlet sites than at the Eastern and Western Branch sites (Figure IV.14), but there were no consistent seasonal trends in biomass. Approximately half of the measured BMA biomass occurred in the upper 1 cm of sediment.

Typical time courses of DO during the incubations are shown in Figure IV.15. Linear slopes were fit to the results for DO and each nutrient species and used to compute the mean net fluxes shown in Figures IV.16 through IV.22 after correcting sediment cores for the water blanks.

Net fluxes of DO were into the sediments in the dark and out of the sediments in the light, confirming the dominance of microbial respiration at night and BMA photosynthesis during the day (Figure IV.16). With the exception of the Western Branch, daytime DO production exceeded nighttime DO consumption, in many cases by a large amount, suggesting these nearshore sites were net autotrophic due to BMA primary production which likely contributes a significant fraction of total carbon fixation in the Lynnhaven.

Dark DO fluxes at each site were directly related to water temperature, with warmer temperatures leading to higher rates of respiration (Figure IV.17). Dark fluxes were not related to sediment chlorophyll, nor were chlorophyll-normalized rates related to temperature, confirming that the majority of sediment respiration was due to the bacterial community. Dark fluxes were also independent of sediment organic content, which ranged from 0.3 to 4.3% at these sites.

Taken as a whole, DO fluxes in the light were generally related to BMA biomass measured as chlorophyll-a content (Figure IV.17). Rates were not correlated to organic content or water temperature, nor were chlorophyll-normalized rates correlated to temperature. BAM photosynthetic rates were high at most sites regardless of season (Figure IV.16).

Fluxes of NH_4^+ were highest in the warmer months, and generally out of the sediments in the dark and into the sediments or near zero in the light (Figure IV.18). NH_4^+ is the product of organic matter degradation by bacteria in the sediments, which was responsible for the dark release.

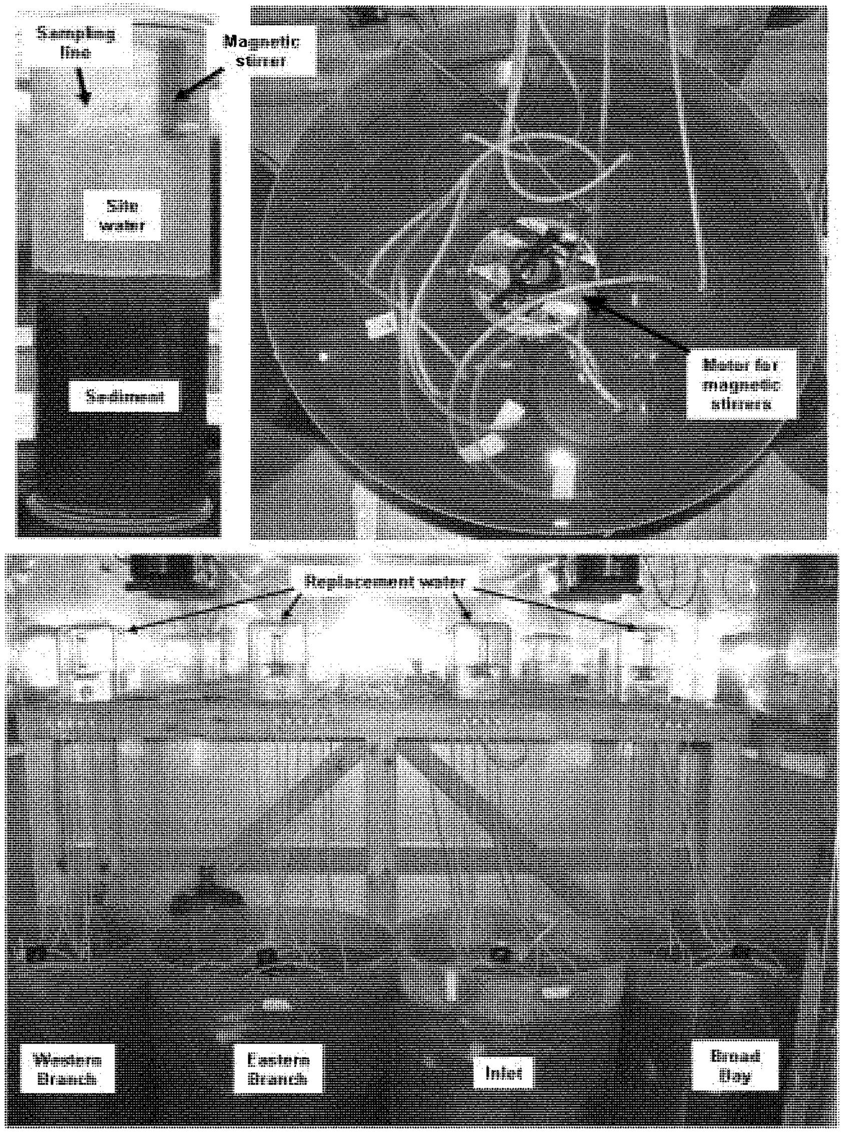


Figure IV.13. Experimental design for sediment flux experiments. Four mesocosms were filled with site water, four sediment cores with overlying water, and two cores with water only to serve as controls. Core water was mixed with a central magnetic stirrer, and hourly samples withdrawn from each core were replaced by site water held in reservoirs ("replacement water").

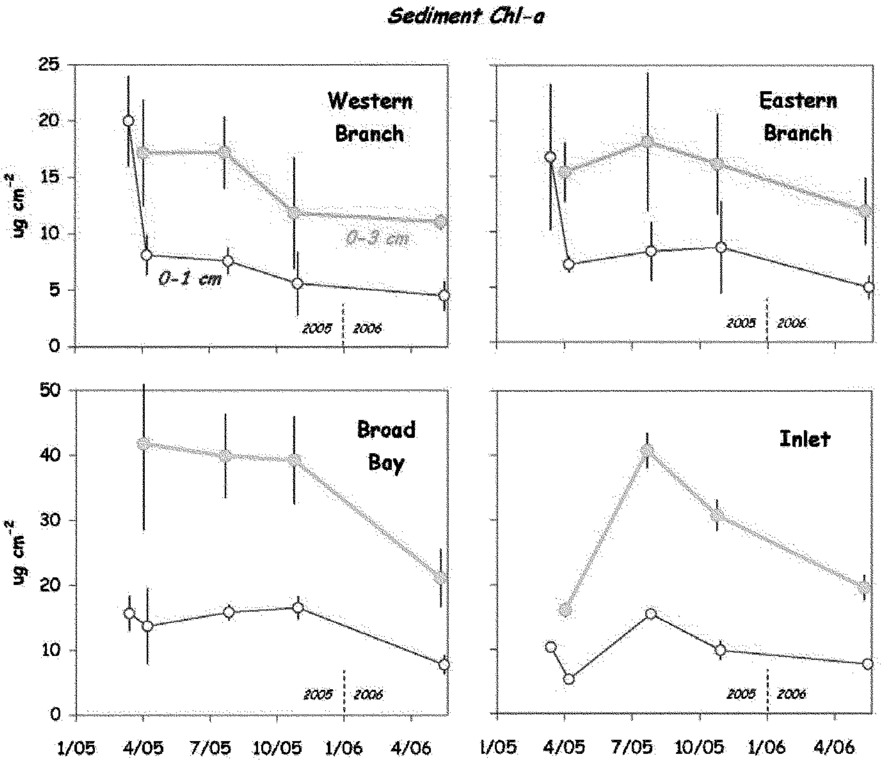


Figure IV.14. Chlorophyll-*a* concentrations measured in the top 1 and 3 cm of sediment at each site. Error bars denote 1 standard deviation.

Uptake by BMA in the light to support photosynthetic production was enough to greatly reduce, eliminate, or completely reverse this release (Figure IV.18). Fluxes of NO_X^- were much lower than for NH_4^+ and mostly centered around zero (Figure IV.19; note different scales between Figures IV.18 and IV.19). The net uptake of NO_X^- at the Eastern Branch and Inlet sites in November 2005 was likely due to denitification. Fluxes of PO_4^{3-}, also a by-product of organic matter degradation by bacteria, were often small and highly variable with no consistent trends (Figure IV.20).

Since NH_4^+ and PO_4^{3-} remineralization and subsequent release from sediments is the result of bacterial decomposition of organic matter, rates in the dark (in the absence of BMA production) should generally be correlated to dark DO consumption (i.e., respiration), although BMA have been shown to take up nutrients in the dark to support

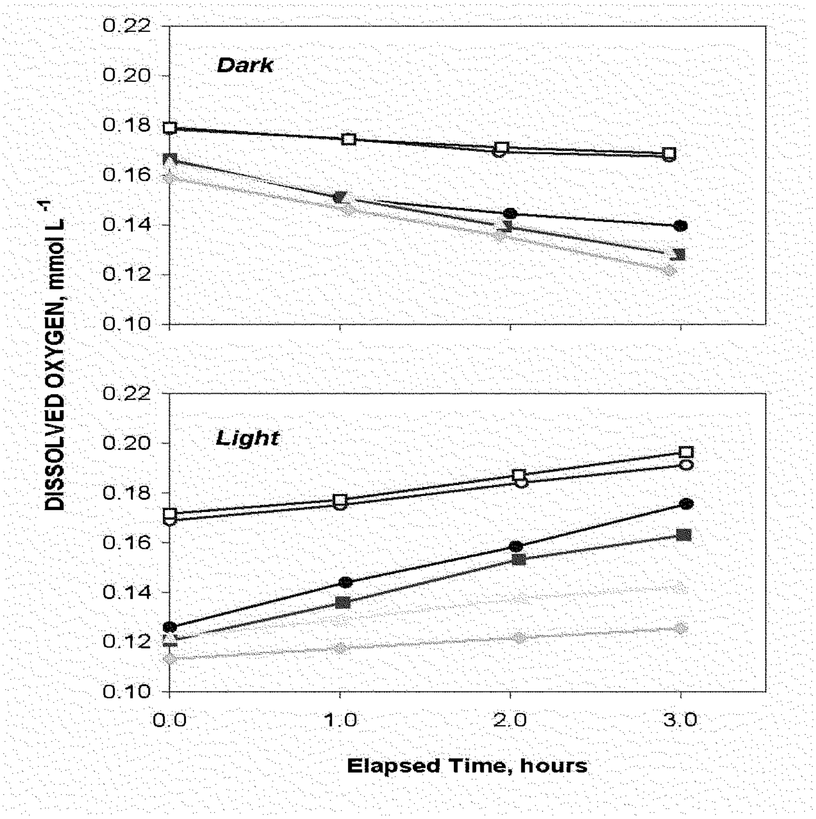


Figure IV.15. Typical time course for DO incubated in the dark and light. Filled symbols depict the sediment cores; open symbols depict the water blanks.

subsequent daytime production. While the relationships contained scatter, dark nutrient releases were generally correlated to dark DO consumption and therefore water temperature (Figure IV.21). Scatter was likely the result of dark BMA uptake and coupled nitrification-denitification. To assess the potential for the former, the rates of nutrient uptake measured in the light were compared to computed BMA demand for nutrients based on DO production rates (Figure IV.16) and molar conversions for nitrogen (9:9:1 O_2:C:N, F. Parker unpublished data) and phosphorus (106:106:1 O_2:C:P, Redfield ratios). With one exception, computed BMA nutrient demand was always greater than measured uptake in the light, suggesting a large amount of BMA demand is satisfied by uptake at night (Figure IV.22).

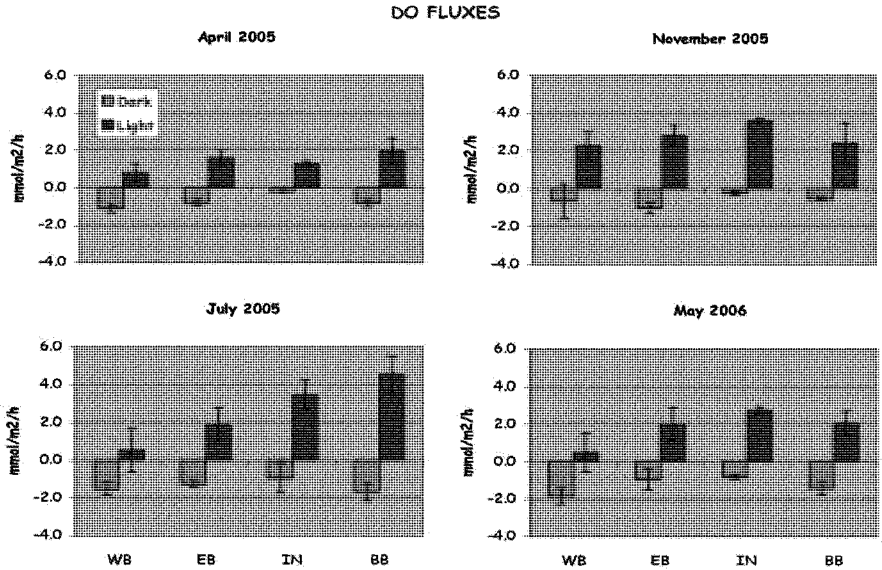


Figure IV.16. Net sediment-water fluxes of dissolved oxygen by site and date. Positive values reflect a release to the water; negative values indicate uptake by the sediments. Error bas denote 1 standard deviation.

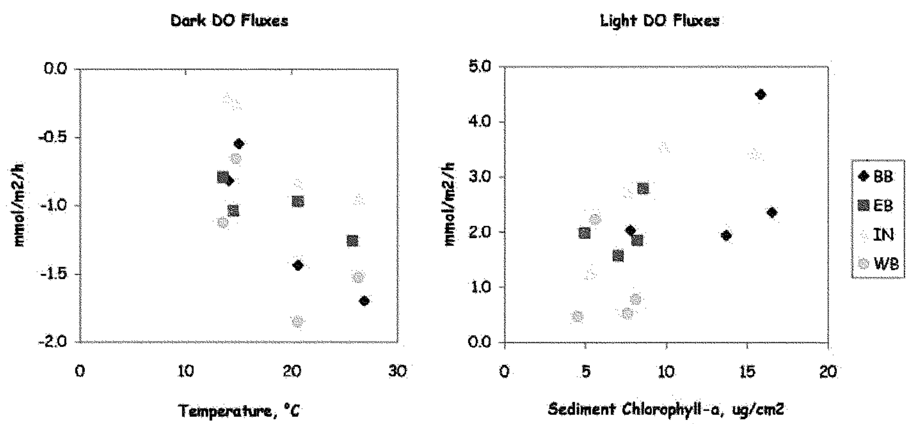


Figure IV.17. Relationship of net sediment-water DO fluxes to water temperature in the dark (left) and sediment chlorophyll in the light (right).

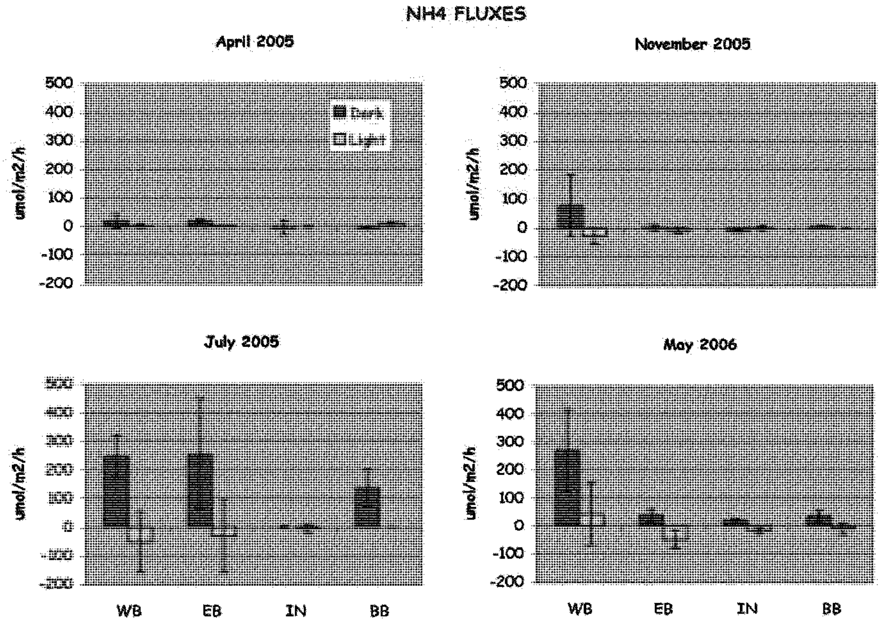


Figure IV.18. As for Figure IV.16, but for fluxes of NH_4^+.

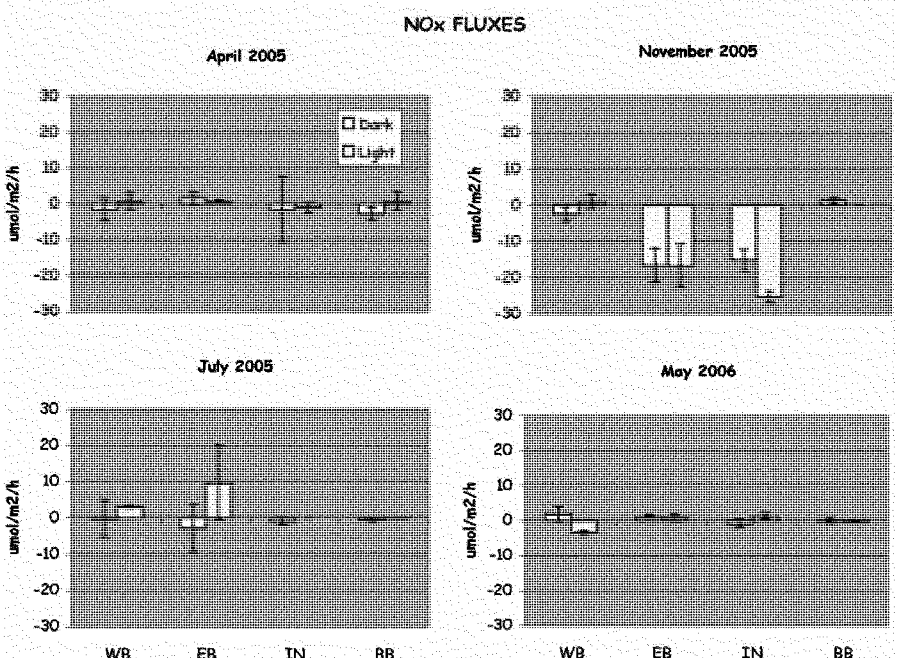


Figure IV.19. As for Figure IV.16, but for fluxes of NO_x^- (NO_2^- + NO_3^-).

Our results confirm the importance of BMA in the Lynnhaven River, as reported for other shallow nearshore systems (e.g., Anderson et al., 2003). While sediment-water fluxes for deeper estuaries are typified by uptake of DO and release of nutrients due to respiration and subsequent remineralization, BMA have the potential to completely reverse these heterotrophic fluxes during the day due to photosynthetic biomass production. The BMA-associated biomass and sediment flux rates determined in this study should serve as useful calibration data for eutrophication and water quality modeling efforts in the Lynnhaven.

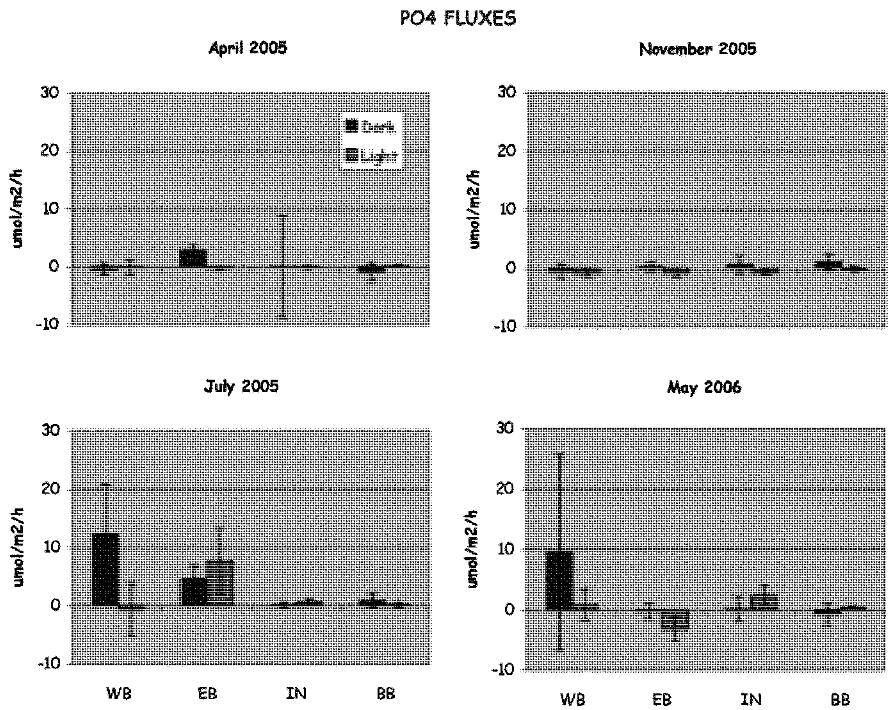


Figure IV.20. As for Figure IV.16, but for fluxes of PO_4^{3-}.

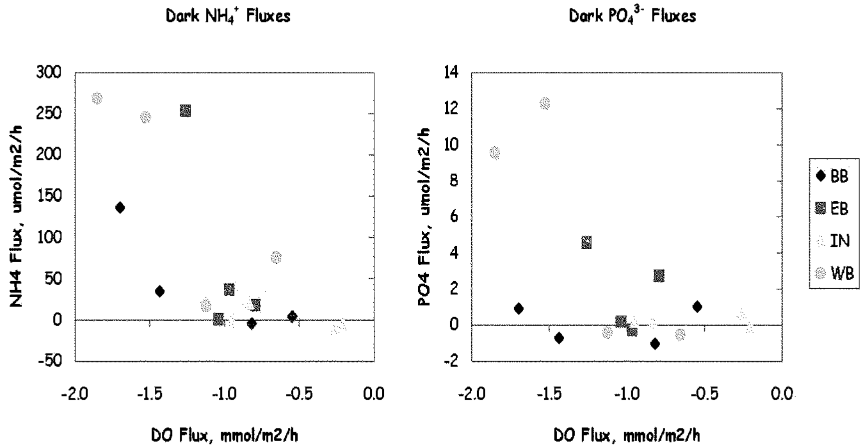


Figure IV.21. Relationship of net sediment-water nutrient and oxygen fluxes in the dark.

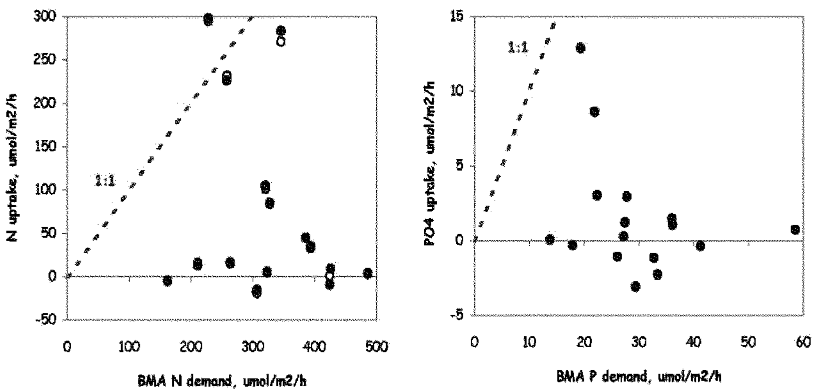


Figure IV.22. Relationship of computed BMA nutrient demand in the light vs. computed uptake in the light. Filled symbols in the plot on the left are for NH_4^+ only; open circles behind the points are for $NH_4^+ + NO_x^-$.

IV-2-3. Sediment critical shear stress measurements

The calculation of sediment concentration in the CE-QUAL-ICM model has a critical dependence on the determination of critical shear stress, which varies spatially and seasonally in the Lynnhaven River. For this reason, a series of surveys were conducted to measure critical shear stress in each branch in different seasons.

An initial bottom sediment mapping survey of the Lynnhaven River Basin was carried out by VIMS to characterize spatial distributions of sediment grain size, water content, etc. Based on the results of this survey, four sites were selected to represent the different environments of the bay and to characterize spatial variability. These sites are located near the Inlet entrance, in the Lower Western and Eastern Branches, and in Broad Bay. These sites were visited 3 times between autumn 2003 and autumn 2004 to conduct erosion experiments. At least two of the erosion testing sites remained fixed as index sites for characterizing seasonal variability. The other two erosion testing sites were moved to increase spatial coverage, depending on the results of the sediment mapping survey.

The sediment was characterized at 19 locations, as shown in Figure IV.23. The results of this sediment characterization survey are shown in Figure IV.24. It is readily seen that the upstream silt and clay fractions give way to the sand fraction moving toward the Inlet in any of the 3 branches.

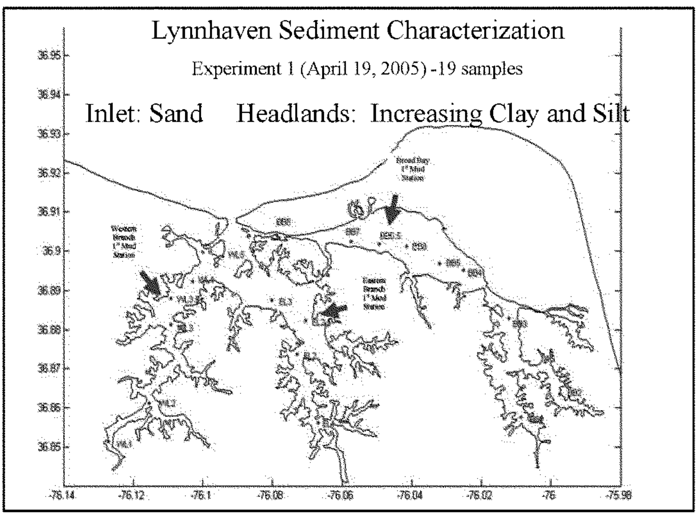


Figure IV.23. Locations for 19 samples characterized for grain size prior to critical shear stress surveys.

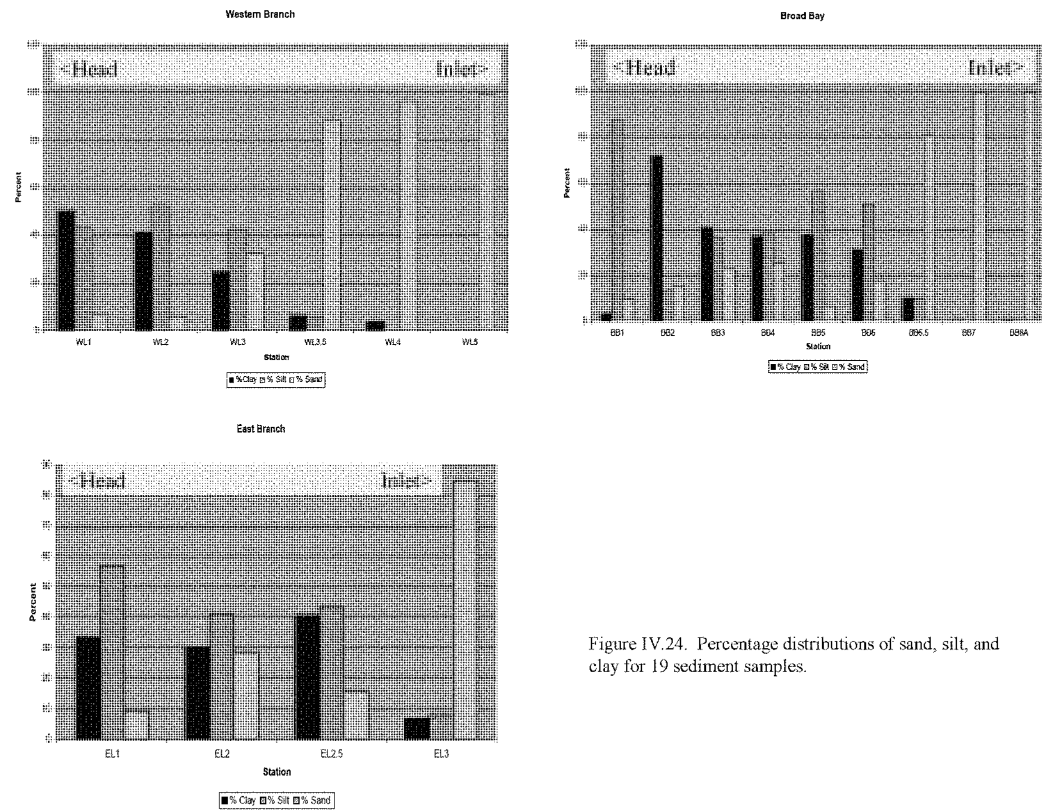


Figure IV.24. Percentage distributions of sand, silt, and clay for 19 sediment samples.

Erosion tests were carried out using an existing erosion testing system, called a microcosm system, operational at Horn Point Laboratory. This Microcosm system consists of 2 10-cm Gust Microcosms (Gust and Mueller, 1997), a Campbell Datalogger connected to a laptop computer, a Fluid Metering Inc. (FMI) positive displacement pump, 2 turbidimeters, and 2 Maxon precision motors. The Microcosms use a spinning disk with central suction to generate a controllable, nearly uniform shear stress (Gust and Mueller, 1997). The Campbell Datalogger controls the pump and motor and collects and stores data.

During erosion experiments, a sequence of increasing levels of shear stress is applied to the undisturbed cores. The effluent from each Microcosm is passed through a turbidimeter and time series of turbidity are measured. The effluent is collected, filtered and weighed to determine the actual mass eroded during each step, which is used to calibrate the turbidimeter. HPL and VIMS shared the filtering responsibilities, and VIMS carried out all filter analyses. Erosion rate is subsequently calculated as the product of pumping rate and suspended sediment concentration.

There were a total of 3 critical shear stress surveys conducted in May 2005, February 2006, and August 2006. It is important to measure at different times of the season because the sediment erodibility could be affected by the activity due to bio-turbation. The locations of the erodibility core sites for all 3 surveys are shown in Figure IV.25.

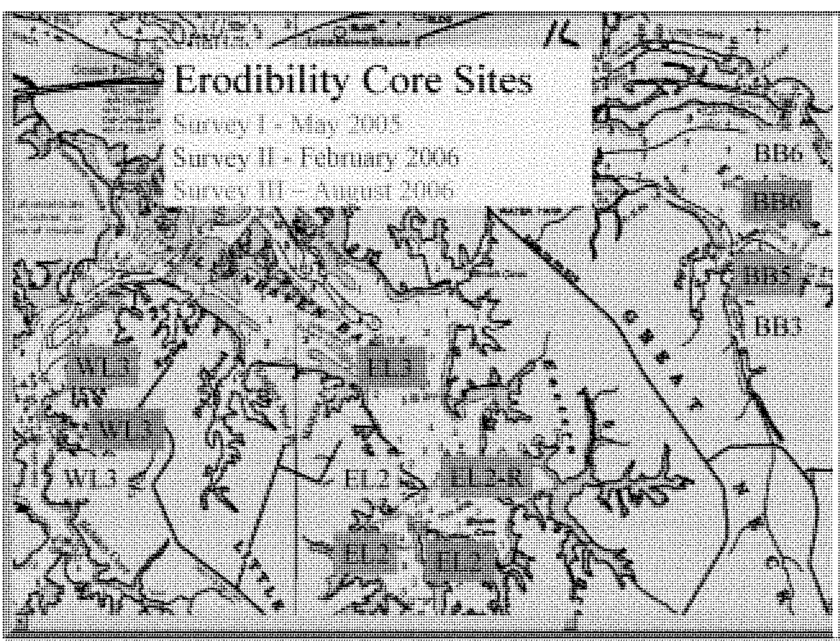


Figure IV.25. Locations of erodibility core sites for all 3 critical shear stress surveys.

Critical stress profiles for all twenty-four cores that were processed from the three field erosion studies are shown in Figure IV.26. X-axis is critical shear stress in Pascals, and Y-axis is eroded mass in kilograms per square meter. The plots of the cores are color-coded so that all cores from May 2005 are green, those from February 2006 are blue, and those from August 2006 are red.

The erosion data were analyzed using the erosion formulation of Sanford and Maa (2001). This erosion formulation uses a linear erosion rate expression with depth-varying critical stress to describe both unlimited and limited erosion, with erosion behavior depending on the rate of increase in critical stress relative to the rate of change of bottom shear stress. Results from this formulation are then incorporated into the sediment transport model to represent the real *in situ* sediment erosion rate.

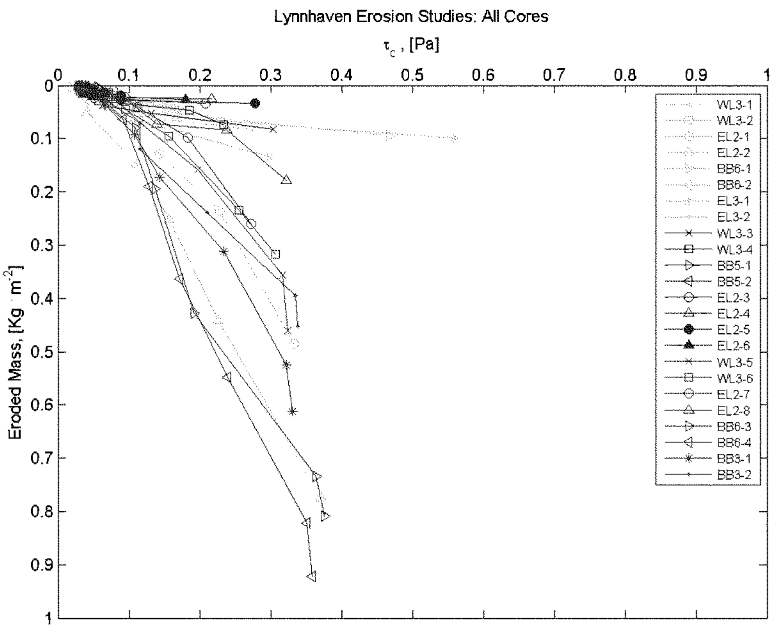


Figure IV.26. Critical stress profiles for all twenty-four cores that were run from the three field erosion studies. X-axis is critical shear stress in Pascals, and Y-axis is eroded mass in kilograms per square meter.

IV-2-4. VIMS dataflow surveys

The development of new water quality standards for turbidity, chlorophyll, and dissolved oxygen, has placed new requirements on accurate measurements of the temporal and spatial variability of water quality constituents. Detailed ecosystem modeling also requires high density spatial measurement for model calibration and validation. Until recently our capacity to measure, monitor, and evaluate water quality constituents in detail over ecologically relevant regions and time scales was limited. However, there has been recent application in Virginia of a new state-of-the-art DATAFLOW Surface Water Quality Mapping System (www.VECOS.org) for high-speed, high-resolution mapping of surface water quality from small vessels capable of sampling shoal, littoral areas. Such a mapping system has been demonstrated to have practical application in the determination of attainment of water quality criteria constituents in shallow water designated use areas. Here we have implemented these new technologies to provide information over small spatial scales to assist in the monitoring of and modeling of light attenuation, chlorophyll concentrations, surface dissolved oxygen, and other water quality conditions in the Lynnhaven River system.

DATAFLOW Mapping System

DATAFLOW is a compact, self-contained surface water quality mapping system, suitable for use in a small boat operating at speeds of up to 25 KT. The system collects water through a pipe ("ram") deployed on the transom of the vessel, pumps it through an array of water quality sensors, and then discharges the water overboard. The entire system from intake ram tube to the return hose is shielded from light to negate any effect high-intensity surface light might have on phytoplankton in the flow-through water that is being sampled. A blackened sample chamber is also used to minimize any effect of light on measurements by the fluorescence probe.

The DATAFLOW mapping system collects a sample once every 2-4 seconds. The resulting distance between samples is therefore a function of vessel speed. An average speed of 25 knots results in one observation collected every 40-60 m.

The DATAFLOW system has a YSI (Yellow Springs Instruments, Inc.) 6600 sonde equipped with a flow-through chamber. The sensors include a Clark-type 6562 DO probe, a 6561 pH probe, a 6560 conductivity/temperature probe, a 6026 turbidity probe, and a 6025 chlorophyll probe. The sonde transmits data collected from the sensors directly to a 600 MHz embedded computer board contained in a waterproof Pelican case using a data acquisition system created with LabVIEW software (National Instruments Corporation, Austin, TX). Custom software written in the LabVIEW environment provides for data acquisition, display, control, and storage. Real-time graphs and indicators provide feedback to the operator in the field, ensuring quality data is being collected. All calibrations and maintenance on the YSI 6600 sondes are completed in accordance with the YSI, Inc. operating manual methods (YSI 6-series Environmental Monitoring Systems Manual; YSI, Inc. Yellow Springs, OH). Table IV.3 provides the precision, accuracy and minimum detection limits of the sensors.

Table IV.3. Precision and accuracy of YSI Data (model 6600)

PARAMETER	UNITS	PRECISION	ACCURACY	MDL
DO	% Saturation	0.1%	± 2%	0 %
DO	mg/L	0.01mg/L	0.2mg/L	0 mg/L
Salinity	ppt	0.01ppt	0.1ppt	0 ppt
Temperature	°C	0.01°C	±0.15°C	-5°C
pH	unit	0.01units	±0.2units	0 units
Turbidity	NTU	0.1NTU	2 NTU	0 NTU
Chlorophyll	µg/L Chl	0.1µg/L Chl	-	0 µg/L Chl

The DATAFLOW system was equipped with a Garmin GPSMAP 168 Sounder. This unit served several functions including chart plotting, position information, and depth. The unit was WAAS (Wide Area Augmentation System) enabled and provided a position accuracy of better than three meters 95 percent of the time. The NEMA 0183 data sentence containing all pertinent position and depth information was output to the SBC data acquisition system.

The DATAFLOW system utilized a SBC data acquisition system for data collection and storage. The system was based on 600 MHz single, embedded board computer designed to run on a Windows Intel platform. All data, including latitude and longitude, was collected simultaneously in one file, removing any errors associated with merging separate files into one.

Calibration Sampling

A total of eight calibration stations were sampled along the cruise tracks each month. Stations were selected to maximize the range of values that are seen along a track (e.g., when moving up a tributary with a salinity gradient, samples were taken to get a high, medium, and low salinity value). Extra sampling supplies were available to sample more stations under special conditions such as in areas of large blooms. At each station the boat was stopped and water samples were collected from the effluent tubing of the DATAFLOW System (sampling water depth of approximately 0.25 - 0.5 m) for total suspended solids (TSS), volatile suspended (VSS), chlorophyll-a, chlorophyll-b, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), total phosphorus (TP), particulate inorganic phosphorus (PIP), and dissolved oxygen (DO) for processing with the Winkler method. At these stations secchi depth and a vertical profile of photosynthetically available radiation (PAR) were also measured. Samples for TSS, VSS, DIN, DIP, and chlorophyll were collected in darkened bottles, which were rinsed three times with ambient water before filling. Samples for DIN, DIP, chlorophyll and pheophytin were immediately filtered into sterile Whirl-Pak™ bags upon collection. These were then packed on ice and returned to the laboratory where they were stored at -20°C. Samples were then delivered to the VIMS Analytical Service Center, Gloucester Point, VA for further processing. Additionally, at each verification station light attenuation was measured from in situ light profiles using EPA-approved LI-COR (LI-COR Biosciences, Lincoln, NEB) underwater quantum sensors.

Quality Assurance and Quality Control

The quality assurance procedures followed in this project were documented in "Work/Quality Assurance Project Plan for Spatially Intensive Water Quality Monitoring (For the Period: April 1, 2004 through June 30, 2004)". This plan was submitted and approved by EPA Chesapeake Bay Program and the Virginia Department of Environmental Quality, Richmond, Virginia.

All field data were recorded on specially prepared field data sheets. The initials of the person recording the data were recorded on each data sheet. The raw data sheets were reviewed for possible missing data values due to sample collection problems prior to data entry. These sheets were filed in the VIMS laboratory. A cruise logbook was also kept.

Results

Dataflow mapping cruises were undertaken approximately monthly from March 2005 through November 2005 and again March 2006 through November 2006. The archived data and visualized tracks of surface temperature, salinity, dissolved oxygen, turbidity, chlorophyll and pH are available at the website www.VECOS.org. Figure IV.27 shows the typical cruise tracks with the range of turbidities recorded during the May 24, 2005 cruise, and the reaches of the of the cruise tracks that are presented as examples in subsequent figures.

Regressions of calibration station sample measurements with simultaneous DATAFLOW measurements were used to develop Lynnhaven-specific calibration of the in vivo measurements. Figure IV.28 shows the regression of the DATAFLOW turbidity measurements to downwelling light attenuation (K_d) profiles for all calibration stations during 2006. Light attenuation was then used to calculate light at depth using the standard Lambert-Beer relationship,

$$I_z = I_o \exp [(-K_d)(Z)] \qquad \text{(IV-1)}$$

where I_z is light at depth Z, I_0 is light at surface, and K_d is the light attenuation coefficient.

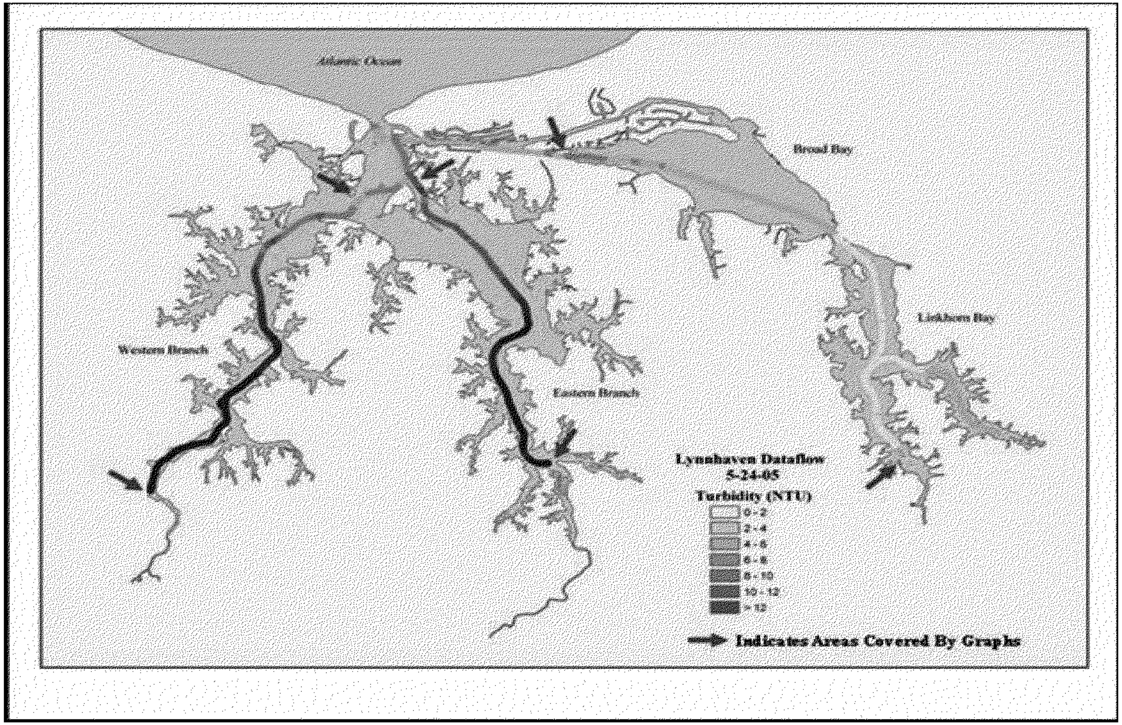


Figure IV.27. Lynnhaven River system DATAFLOW cruise tracks showing turbidity levels during the 5-24-05 cruise. Arrows indicate the reaches that are presented in subsequent graphs in this chapter.

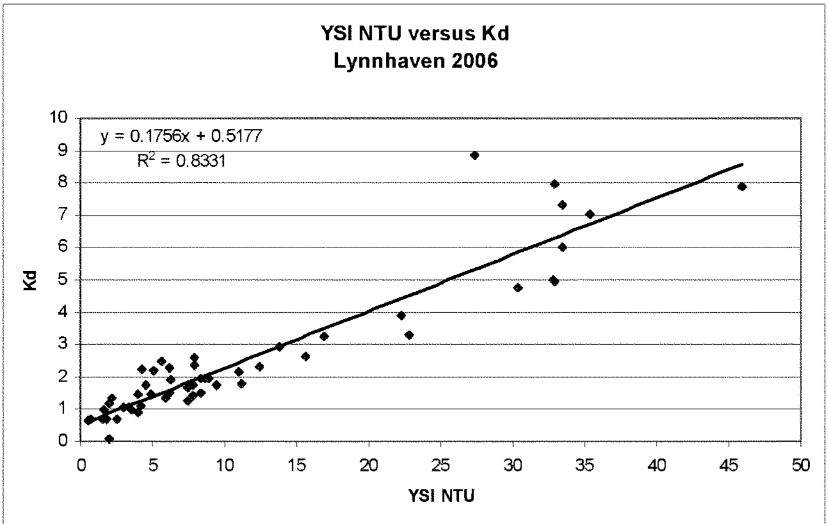
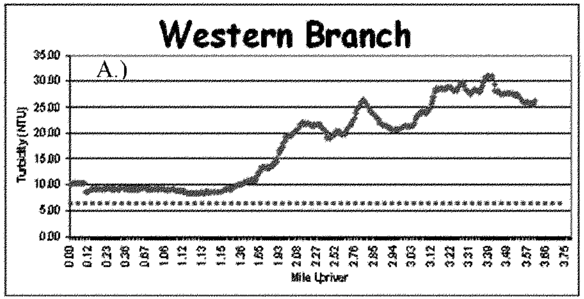


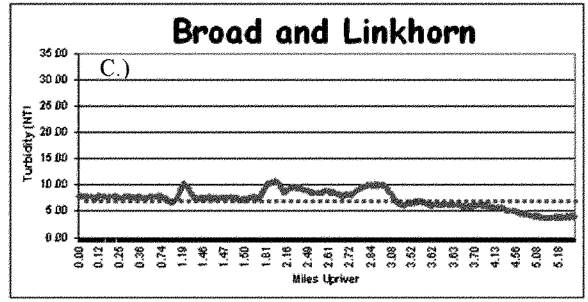
Figure IV.28. 2006 verification station YSI NTU (turbidity) vs. light attenuation (Kd)

Figures IV.29A, B, and C show representative concentration-distance plots of turbidities (NTU) for the individual branches of the Lynnhaven system. Using the 2006 Lynnhaven system NTU to light attenuation relationship (Figure IV.28) the turbidity (~6 NTU) that is equal to 22% of surface irradiance at 1m bottom depth is provided for a reference. Typically, 22% of surface irradiance is used as a standard by EPA and the Commonwealth of Virginia to define sufficient light available for SAV sustained growth.

All three systems had comparable turbidities near the inlet of the Lynnhaven. Turbidities in the Eastern and Western Branches increased precipitously with distance upstream during July (Figures IV.29A and IV.29B) and during most other months (data not shown). Levels in Broad and Linkhorn Bays were much lower than the other two branches (Figure IV.29C). Turbidities in parts of Linkhorn Bay were lower compared to Broad Bay.

Figure IV.30 shows the spatially averaged turbidity for each of the three individual branches of the Lynnhaven system for the eight cruises in 2006. Averaged turbidities were seasonally highest in September of 2006 and highest in the Eastern Branch. Averaged turbidities in Broad and Linkhorn Bays were lower during all months than the Eastern and Western Branches.





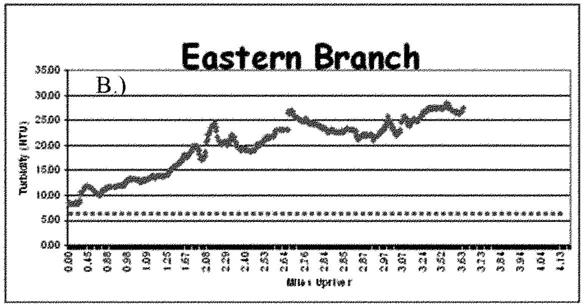


Figure IV.29. Concentration-distance plots of turbidity along the A.) Western Branch, B.) Eastern Branch, and C.) Broad and Linkhorn Bays during July 2006. Dotted red lines indicate turbidity levels where light at 1m depth is equal to 22% of surface irradiance (SAV light criteria).

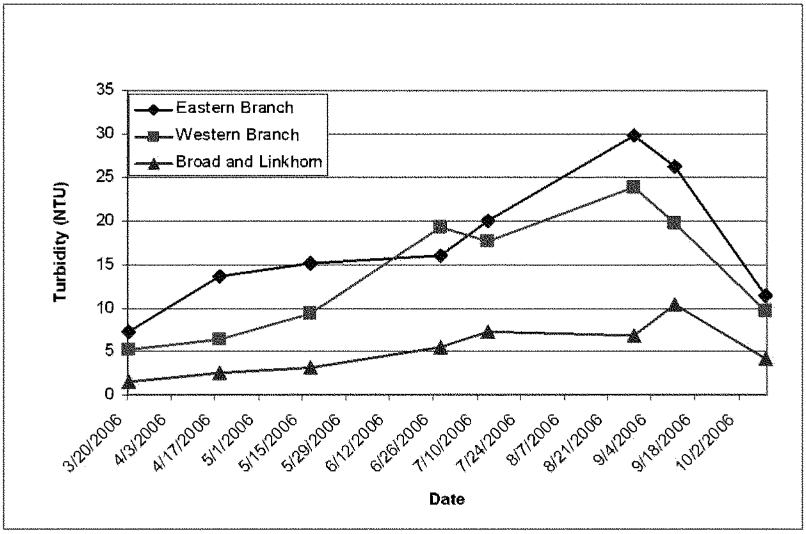


Figure IV.30. Spatially averaged turbidities (NTU) for the individual branch cruise track reaches for each monthly DATAFLOW cruise in 2006.

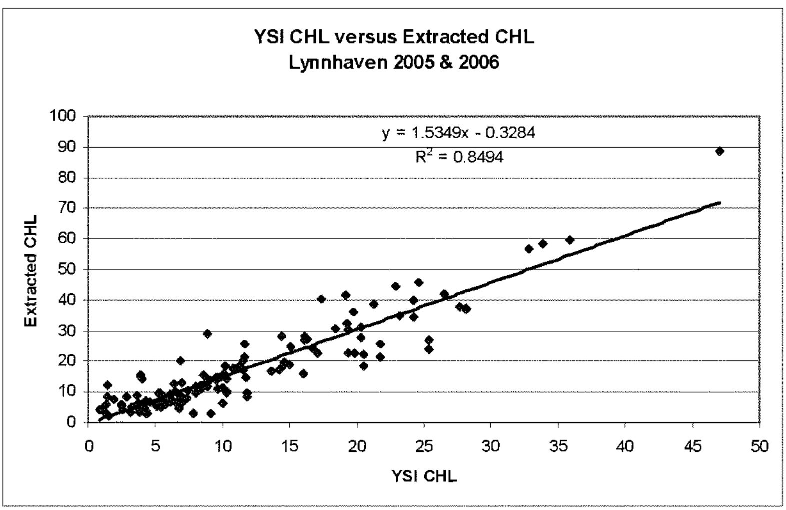


Figure IV.31. 2005-2006 verification station YSI chlorophyll vs. extracted chlorophyll.

All in vivo DATAFLOW chlorophyll data have been converted to extracted chlorophyll values using the 2005 and 2006 Lynnhaven system YSI chlorophyll to extracted chlorophyll relationship developed from the calibration station data (Figure IV.31).

Figures IV.32A, B, and C show representative concentration-distance plots of chlorophyll for the individual branches of the Lynnhaven system for July 2006. All three branches have low comparable chlorophyll levels in the vicinity of the inlet. In July 2006 these levels were comparable to the summertime chlorophyll standards set by the Virginia DEQ for the James River (red line). Rapid increases in chlorophyll were observed with distance upstream for the Eastern and Western Branches. There was some increases in Broad and Linkhorn Bays but during July concentrations only reached approximately 15 µg/l.

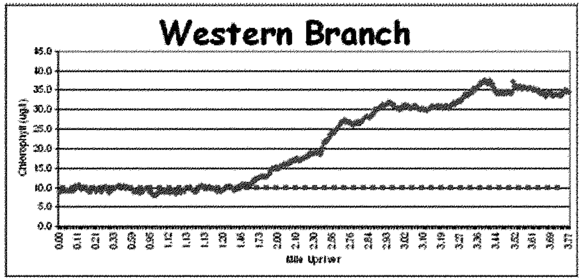
Figure IV.33 shows the spatially averaged chlorophyll concentrations for each of the three individual branches of the Lynnhaven system for the eight cruises in 2006. These data indicate that the average chlorophyll concentrations in all branches of the system exceeded the water quality standards from approximately April through September. The Eastern Branch has the highest levels followed by the Western Branch and the Broad and Linkhorn Bays

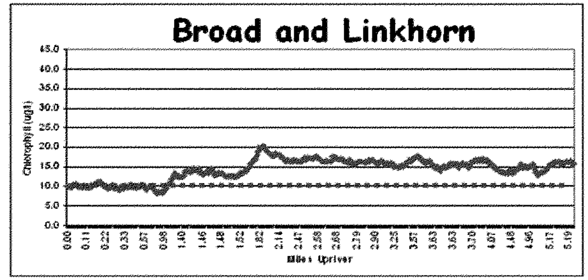
Figures IV.34A, B, and C show representative concentration-distance plots of dissolved oxygen for the individual branches of the Lynnhaven system for July 2006. All three branches recorded high, daytime, dissolved oxygen levels that varied little from the inlet region to the upper regions of the branches. In July 2006 these levels met the summertime dissolved oxygen standards set by the Virginia DEQ for the James River (red line) of 4.3 mg/l.

Figure IV.35 shows the spatially averaged surface dissolved oxygen concentrations for each of the three individual branches of the Lynnhaven system for the eight cruises in 2006. These data indicate that the average dissolved oxygen concentrations in all branches of the system met the standards throughout the year.

Summary

Water quality measurements using spatially intensive water quality mapping (DATAFLOW) for the Lynnhaven system demonstrated that Broad and Linkhorn Bays had distinctly better water quality that the Western and Eastern Branches. Water quality was generally best in all regions in the vicinity of Lynnhaven Inlet and rapidly deteriorated with distance upriver in both the Western and Eastern Branches. Turbidity levels in both the Western and Eastern Branches generally exceeded that required for SAV growth to 1m while levels appeared sufficient for SAV growth in both Broad and





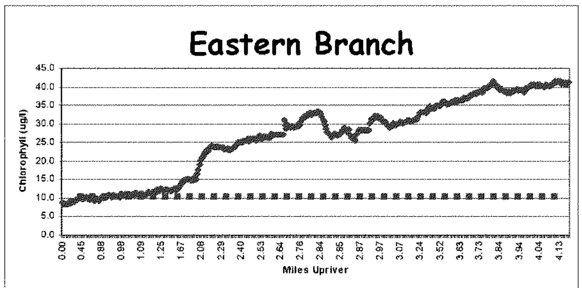


Figure IV.32. Concentration-distance plots of chlorophyll along the A.) Western Branch, B.) Eastern Branch, and C.) Broad and Linkhorn Bays during July 2006. Dotted red lines indicate DEQ summer chlorophyll standards for the James River of 10 µg/l.

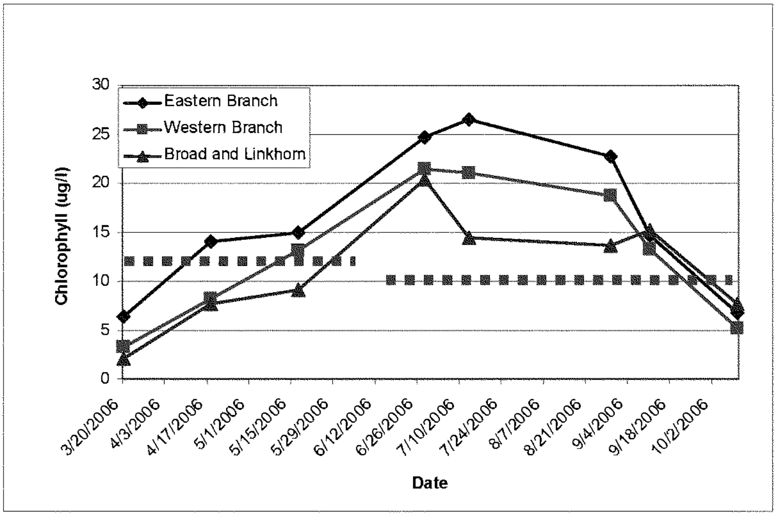
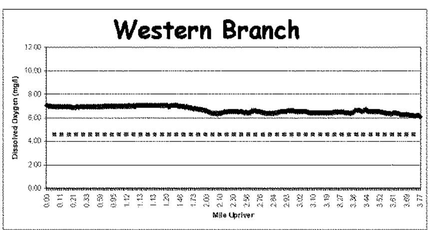
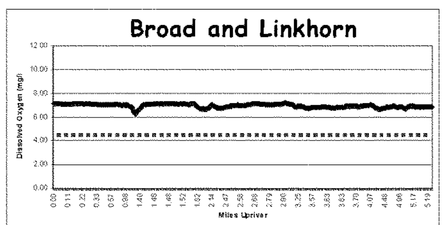


Figure IV.33. Spatially averaged chlorophyll concentrations for the individual branch DATAFLOW cruise track reaches for each monthly cruise in 2006. Red lines indicate the Va. DEQ chlorophyll standards of 12 μg/l for March 1 - May 31 and 10μ for July 1 – September 30.





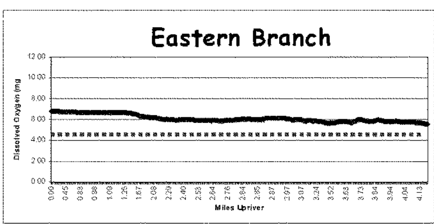


Figure IV.34. Concentration-distance plots of dissolved oxygen along the A.) Western Branch, B.) Eastern Branch, and C.) Broad and Linkhorn Bays during July 2006. Dotted red lines indicate DEQ surface dissolved oxygen standards for the James River of 4.3 mg/l.

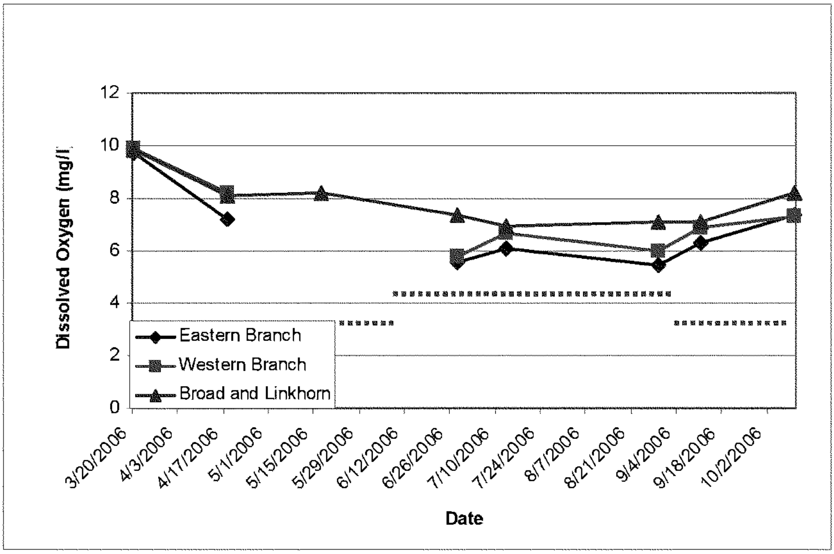


Figure IV.35. Spatially averaged surface dissolved oxygen concentrations for the individual branch DATAFLOW cruise track reaches for each monthly cruise in 2006. Red lines indicate the Va. DEQ dissolved oxygen of 12 µg/l for March 1 - May 31 and 10 µg/l for July 1 – September 30.

Linkhorn Bays. These measurements agreed with the current distributions of SAV that are currently only found in Broad and Linkhorn Bays.

Chlorophyll levels were above the numeric standards in most areas except for the region near Lynnhaven Inlet from April through September. Highest concentrations occurred during July and in the upper reaches of the Western and Eastern Branches where concentrations approached 40 µg/l during July 2006. Daytime surface dissolved oxygen concentrations were generally good and met the standards throughout the system. Nightime concentrations were not measured, but concentrations could be expected to drop significantly in the upper reaches of the Western and Eastern Branches due to the high phytoplankton biomass and other factors.

IV-2-5. VIMS high-frequency time series measurements

High frequency water quality measurements were obtained for use in model calibration, assessing water quality, and understanding the Lynnhaven ecosystem from 2005 to 2008 with a network of *in situ* sensors (Figure IV.36). Self-cleaning, internally-logging WET Labs ECO fluorometers (www.wetlabs.com/products/eflcombo/fl.htm) were deployed approximately 0.5 m below the surface (MLLW) to measure phytoplankton biomass as chlorophyll-a (chl-a), turbidity expressed in nephelometric turbidity units (NTU), and water temperature. Since seagrass has traditionally been found in Broad Bay (web.vims.edu/bio/sav) and is highly dependent on adequate light penetration, an additional WET Labs fluorometer capable of measuring the concentration of chromophoric dissolved organic matter (CDOM) was also deployed in Broad Bay to enable measurement of all three parameters that affect light penetration (chl-a, NTU, CDOM) in that embayment. A self-cleaning, internally-logging Hydrolab DS-5X instrument (www.hydrolab.com/products/hydrolabds5x.asp) was deployed approximately 0.5 m above the bottom to measure temperature, salinity, and dissolved oxygen (DO) using optical sensor technology. This instrument was deployed in the Eastern Branch in 2005 and the Western Branch in 2006.

Monitoring began in 2005 with a single fluorometer and DS-5X in the Eastern Branch (moved from the lower to upper branch part way through the summer), and both types of WET Labs fluorometers in Broad Bay (Figure IV.36, Tables IV.4 and IV.5). In 2006 new equipment acquisitions allowed us to expand into the upper and lower Eastern and Western Branches. The DS-5X was moved to the upper Western Branch to assess a second location for low DO. To assess the potential for local phytoplankton bloom formation within the Lynnhaven as opposed to advection of blooms from the lower Chesapeake Bay, a final WET Labs fluorometer was deployed at the NOAA tide station on the Chesapeake Bay Bridge-Tunnel (CBBT) fishing pier.

All sensors recorded data at 30-minute intervals and were serviced as frequently as possible (approximately every two weeks). At each servicing, water samples were collected for determination of chlorophyll-a, total suspended solids (TSS – 2006 only), and CDOM concentrations for sensor calibration, and independent measurements of DO and salinity were made with a freshly calibrated Hydrolab to provide data for sensor confirmation. Chlorophyll samples were filtered onto 0.7 µm GF/F filters and frozen until extraction with a 45/45/9.9/0.1% acetone/DMSO/distilled water/diethylamine solution for 24 hours (Shoaf and Lium, 1976) followed by analysis on a model 10-AU Turner Designs fluorometer. TSS samples were filtered onto pre-weighed 0.7 µm GF/F filters and dried to constant weight at 50°C. CDOM samples were filtered through a 0.2 µm membrane filter and frozen until analysis of absorption on a Shimadzu UV-1601 scanning spectrophotometer (Gallegos and Neale, 2002; Gallegos et al., 2005).

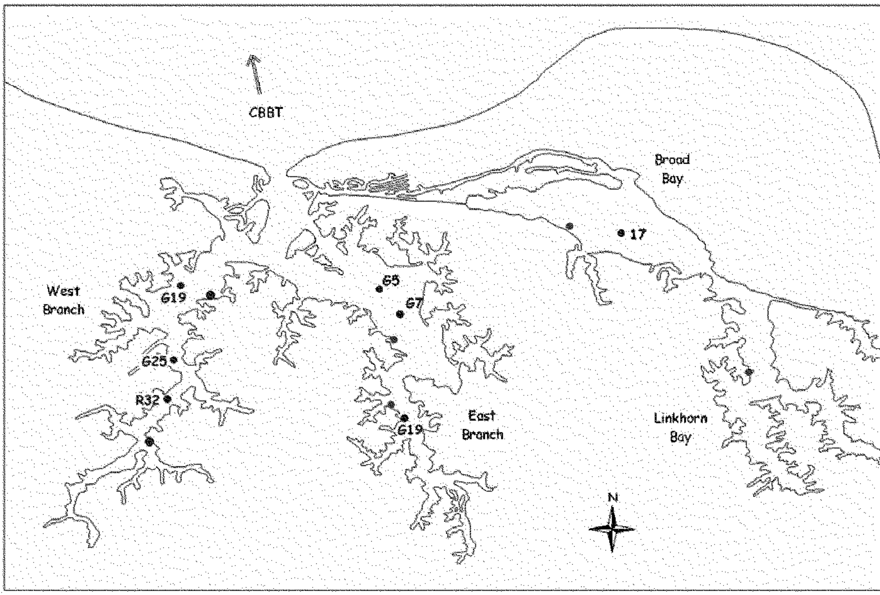


Figure IV.36. Locations of time series sensors. Blue stations are navigational markers used in 2005-06. Sites with dotted circles denote the location of the bottom oxygen sensors. Red stations are docks used in 2007-08. Sites with dotted circles denote the location of the surface oxygen sensors. Green stations are the sites of auxiliary chlorophyll samples collected by Lynnhaven River Now.

Absorption at 440 nm (m^{-1}) was taken as the index of CDOM concentration. Chlorophyll and NTU data from nearby Dataflow calibration stations and long-term Virginia Department of Environmental Quality monitoring stations were also used to develop sensor calibration curves. A sample calibration curve is shown in Figure IV.37. In 2005, Lynnhaven River Now personnel collected shore-based chlorophyll samples (analyzed at VIMS) at two sites (Fig. 1) for comparison of nearshore concentrations to those measured at the mid-channel *in situ* sensors. All sensor data were quality controlled via visual inspection and through use of the independent DO and salinity data to remove obviously corrupted data due to sensor fouling and malfunction.

One of the key parameters in shallow aquatic systems is the vertical attenuation coefficient of irradiance, k_D, which controls the amount of light available to support both water column and benthic primary production according to Beer's Law:

$$I_z = I_o e^{-k_D z} \qquad \text{(IV-2)}$$

Table IV.4. Sensor deployment locations (navigational markers), dates (excluding gaps), and parameters[1].

	Location	Dates	Parameters
2005			
E. Branch	G7	5/5-8/12	Chl, NTU, T (surface)
		7/7-7/27	T, S, DO (bottom)
	G19	8/17-11/15	Chl, NTU, T (surface)
		7/14-10/22	T, S, DO (bottom)
Broad Bay	17	5/31-9/1	Chl, NTU, T, CDOM (surface)
2006			
Lower W. Branch	G19	4/14-11/8	Chl, NTU, T (surface)
Upper W. Branch	R32[2]	2/16-11/9	Chl, NTU, T (surface)
	R32	5/17-9/22	T, S, DO (bottom)
Lower E. Branch	G7[3]	4/14-11/9	Chl, NTU, T (surface)
Upper E. Branch	G19	4/14-9/20	Chl, NTU (surface)
Broad Bay	17	2/16-8/24	Chl, NTU, T (surface)
		3/9-8/11	CDOM (surface)
CBBT[4]	-	2/16-7/6	Chl, NTU (surface)
2007-08[5]			
Lower W. Branch	see Fig 1	5/17/07-3/26/08	Chl, NTU (surface)
		6/20/07-7/3/08	T, S, DO (surface)
Upper W. Branch	see Fig 1	5/17/07-7/1/08	Chl, NTU (surface)
		9/13/07-6/19/08	T, S, DO (surface)
Lower E. Branch	see Fig 1	5/17/07-7/1/08	Chl, NTU (surface)
Upper E. Branch	see Fig 1	5/17/07-6/5/08	Chl, NTU (surface)
Broad Bay	see Fig 1	5/17/07-7/1/08	Chl, NTU (surface)
Linkhorn Bay	see Fig 1	5/17/07-7/1/08	Chl, NTU (surface)

[1] Parameter abbreviations are as follows: Water temperature (T), Salinity (S), Dissolved oxygen (DO), Chlorophyll-*a* (Chl), Turbidity (NTU), Chromophoric dissolved organic matter (CDOM).
[2] Sensor moved from marker G25 to R32 on 2/23/06 to get farther up the branch.
[3] Sensor moved to marker G5 on 6/29/06 when G7 was hit by a vessel.
[4] NOAA tide station on the Chesapeake Bay Bridge-Tunnel.
[5] Several gaps in the record exist but were excluded due to limited space.

Table IV.5. Coordinates of sensor locations.

	Location	Latitude	Longitude
2005-06			
Lower W. Branch	G19	36°53'17.69"N	76° 6'29.66"W
Upper W. Branch	R32	36°52'9.23"N	76° 6'37.71"W
	G25	36°52'32.64"N	76° 6'33.96"W
Lower E. Branch	G7	36°53'0.43"N	76° 4'16.93"W
	G5	36°53'15.61"N	76° 4'29.49"W
Upper E. Branch	G19	36°51'57.59"N	76° 4'14.19"W
Broad Bay	17	36°53'49.53"N	76° 2'3.07"W
CBBT	-	36°58'0.68"N	76° 6'49.17"W
2007-08			
Lower W. Branch	dock	36°53'12.11"N	76° 6'11.66"W
Upper W. Branch	dock	36°51'43.33"N	76° 6'48.74"W
Lower E. Branch	dock	36°52'45.18"N	76° 4'20.64"W
Upper E. Branch	dock	36°52'5.46"N	76° 4'22.50"W
Broad Bay	dock	36°53'53.55"N	76° 2'34.10"W
Linkhorn Bay	dock	36°52'25.44"N	76° 0'45.68"W

in which I_o and I_z are incident irradiance at the surface and irradiance at depth z, respectively. k_D is controlled by the concentrations of chlorophyll-a, turbidity (as NTU or TSS), and CDOM in the water column. To develop a simple empirical model for predicting k_D as a function of these water quality parameters, data for chlorophyll, NTU, TSS, and k_D measured by the DATAFLOW group at their calibration stations were combined with CDOM concentrations measured as described above at the same stations (water provided by the DATAFLOW group after each cruise) to develop a multiple linear regression. This regression for k_D was then combined with the *in situ* sensor time series data from Broad Bay to compute the amount of light reaching the bottom as this is a key index for survival of submerged aquatic vegetation (SAV) such as eelgrass (*Zostera marina*) which has historically been present in Broad Bay.

Finally, enough funds were saved throughout the project to make possible an extra sensor deployment over an annual cycle in 2007-08 (Tables IV.4-IV.5), combined with measurements of water column primary production and respiration to complement the sediment flux data of Brush and Anderson, make possible a total metabolic budget of the

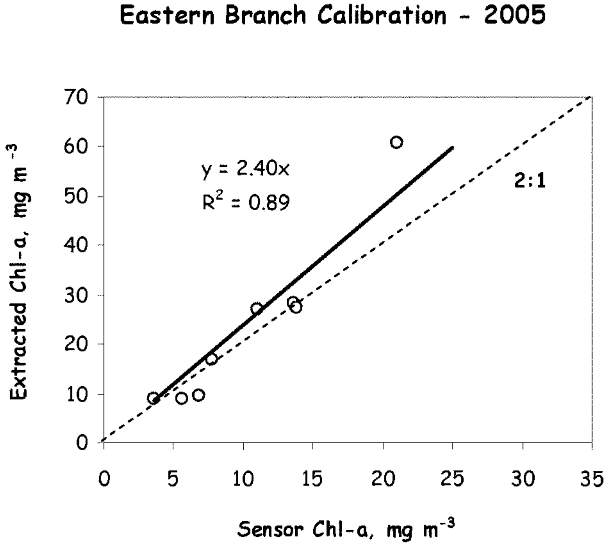


Figure IV.37. Sample calibration plot relating sensor output to measured water quality, in this case chlorophyll-a.

system, and provide critical rate process data for model calibration. WET Labs sensors were deployed on private docks throughout the Lynnhaven (Figure IV.36) and serviced approximately monthly from spring through fall and bimonthly in the winter. During each servicing trip, calibration samples were collected for measurement of chlorophyll and dissolved inorganic nutrients (0.45 µm Supor filters), temperature, salinity, and k_D were measured (using Hydrolab MS5, YSI 6600V2, and Li-Cor LI-1400 and LI-192SA instrumentation), and water samples were returned to VIMS for incubation at field temperatures in 60 mL bottles in a temperature-controlled light gradient box for determination of photosynthesis-irradiance (P-I) curves. Photosynthesis and respiration were measured as the rate of change in dissolved oxygen as measured with Hach HQ40d optical DO sensors. On three trips, sediment cores were collected at each site and incubated in the dark and at saturating irradiance to obtain data from the same annual cycle for comparison to the earlier sediment flux data of Brush and Anderson. Hydrolab and/or YSI sensors were deployed 0.5 m below the surface on selected trips to collect DO data every 30 minutes for computation of metabolism using the free water method for comparison to the incubation results. This annual cycle was recently completed and data are still being analyzed.

Results

Time series data displayed high frequency variations due to tidal and diel cycles, as well as longer-term, event scale and phytoplankton bloom dynamics on the order of 1-2 weeks (Figure IV.38). Shore-based samples had similar concentrations and patterns as the mid-channel, *in situ* sensors, suggesting the latter were reflective of the entire embayment within which they were located (Figure IV.39).

Chlorophyll-a from 2006 showed the expected increasing trend in phytoplankton biomass from the lower to the upper estuary, with highest values in the upper Western Branch (Figure IV.40). Lowest chlorophyll concentrations occurred in Broad Bay. Chlorophyll at all locations was higher than in the lower Chesapeake Bay as measured at the CBBT. A small February bloom at the CBBT also occurred inside the Lynnhaven. The spring phytoplankton bloom in the lower bay typically occurs in April. While none was detected at the CBBT, a late April bloom was detected throughout the Lynnhaven, as were frequent blooms throughout the season. These blooms were higher than at the CBBT, and often occurred at multiple stations. The data suggest that conditions within the Lynnhaven are favorable to bloom formation, and counter an alternative hypothesis that blooms are the result of advection of high chlorophyll water from the lower Chesapeake into the system.

Bottom water hypoxia occurred in both years in the upper branches of the Lynnhaven (Figure IV.41). Values were fairly constant around 5 mg L^{-1} on average in the Eastern Branch, with lower values being limited to the early morning hours as part of the diel cycle. In contrast, large swings in DO appeared to occur in the Western Branch. However, the sensor at this site was repeatedly and heavily fouled throughout the sampling season and appeared to be located within a thick bottom layer of detritus and macroalgae which likely resulted in the low DO. The repeated, rapid declines in DO following each servicing of the sensor and erratic changes in salinity (sensor also fouled) support this conclusion. However, the long term hypoxia from late July through early August appears to have been a real phenomenon, although it is impossible to determine if this was a lower water column event or restricted to the bottom detrital layer at this site.

Phytoplankton blooms in the Lynnhaven as measured by chlorophyll-a concentration often coincided at multiple sites around the system (Figure IV.42). In many cases chlorophyll and turbidity showed similar dynamics suggesting they were driven by the same forces (e.g. rain or wind events), while in other cases they were inversely related to one another, suggesting limitation of photosynthesis by high turbidity. Rain events should lead to runoff which would deliver sediments (thereby increasing turbidity) and nutrients which could stimulate phytoplankton blooms, while wind events would mix bottom sediments and potentially benthic microalgal chlorophyll into the water column. Blooms in 2005 often followed rain events, although the pattern in 2006 was less clear, and it is likely that internal remineralization of nutrients is also a major driver of bloom dynamics in this system.

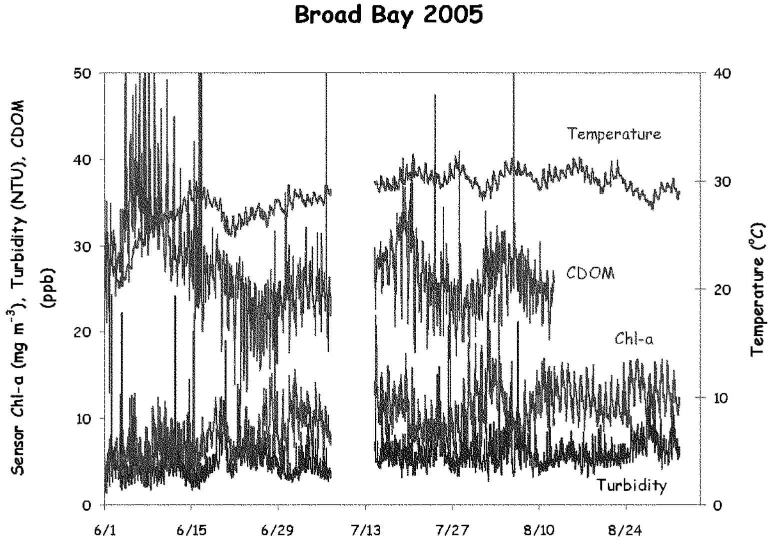


Figure IV.38. Time series measurements from 2005 in Broad Bay.

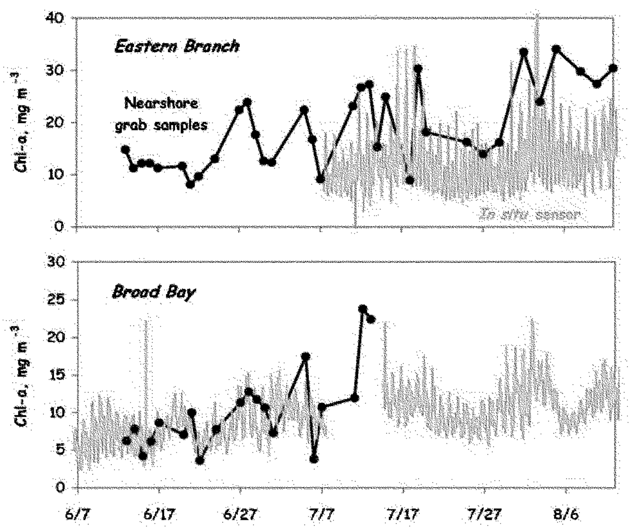


Figure IV.39. Time series of chlorophyll-a collected at shore-based sites by Lynnhaven River Now in 2005 compared to *in situ* fluorometer time series deployed mid-channel at navigational markers.

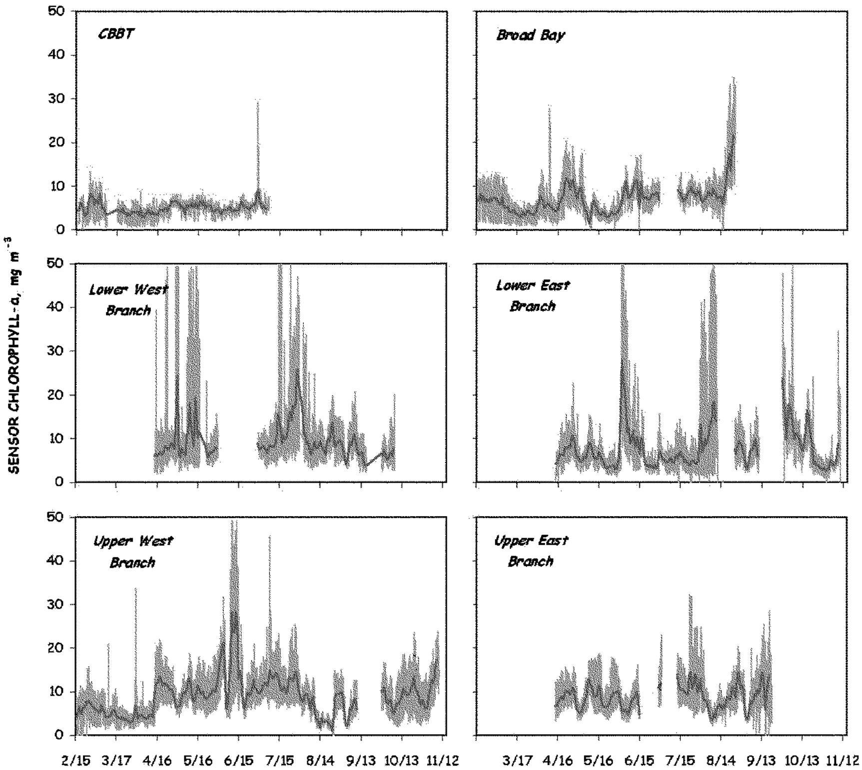
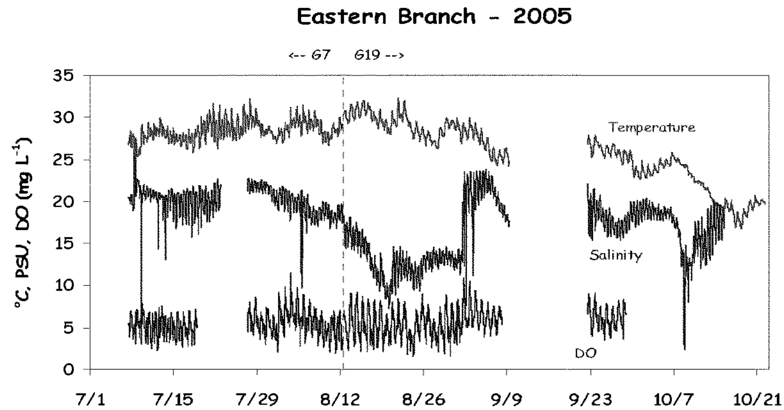


Figure IV.40. Time series measurements of surface chlorophyll-a in 2006. Green lines represent daily averages from the 30-minute data (grey lines).

Dynamics of chlorophyll and DO were linked, presumably through photosynthetic oxygen production, even though DO was measured on the bottom. DO concentrations also appeared closely related to incident irradiance, more so than chlorophyll-a, suggesting the importance of benthic microalgal production and sediment respiration in this system. CDOM and salinity also appeared closely coupled to recent rain events in 2005.



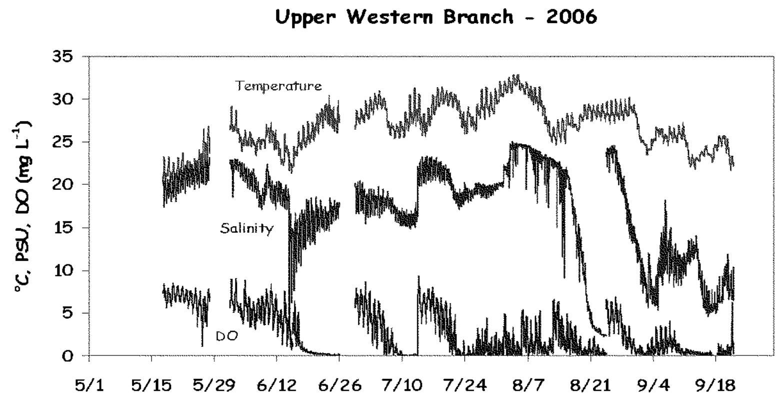
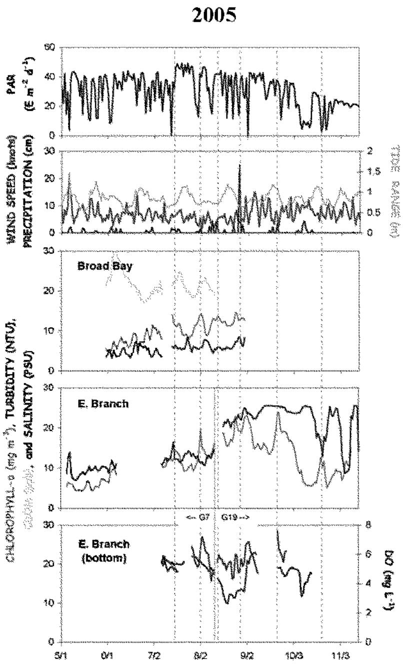


Figure IV.41. Time series measurements of bottom water quality.

Attenuation of light in the Lynnhaven was correlated to both chlorophyll and turbidity, with the latter having the stronger correlation (Figure IV.43a-b). Attenuation did not appear to have a strong correlation with CDOM in this system (Figure IV.43c). Three different multiple regression models for predicting k_D were fit to the data (Table IV.6). The first two used all three attenuating substances, one using NTU for turbidity and the other using TSS, while the third used only chlorophyll and NTU. Model fit was better when turbidity was expressed in NTU units, and inclusion of CDOM did not improve model fit. The resulting regressions reproduced measured k_D well (Figure IV.43d).



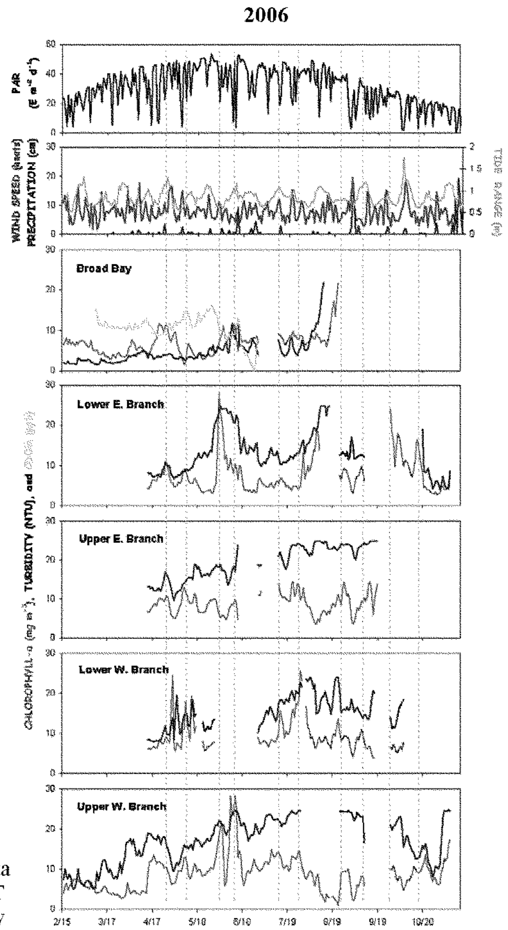


Figure IV.42. Daily average values from the 2005-06 time series sensors plotted with daily irradiance from the Chesapeake Bay Virginia National Estuarine Research Reserve site on the York River (photosynthetically active radiation, PAR), average daily wind speed and total daily precipitation at the Norfolk International Airport (obtained from the NOAA National Climatic Data Center), and daily tide range at the NOAA CBBT tide station. Vertical lines connect approximately co-occurring chlorophyll blooms. Most turbidity sensors were not factory calibrated to read higher than 25 NTU.

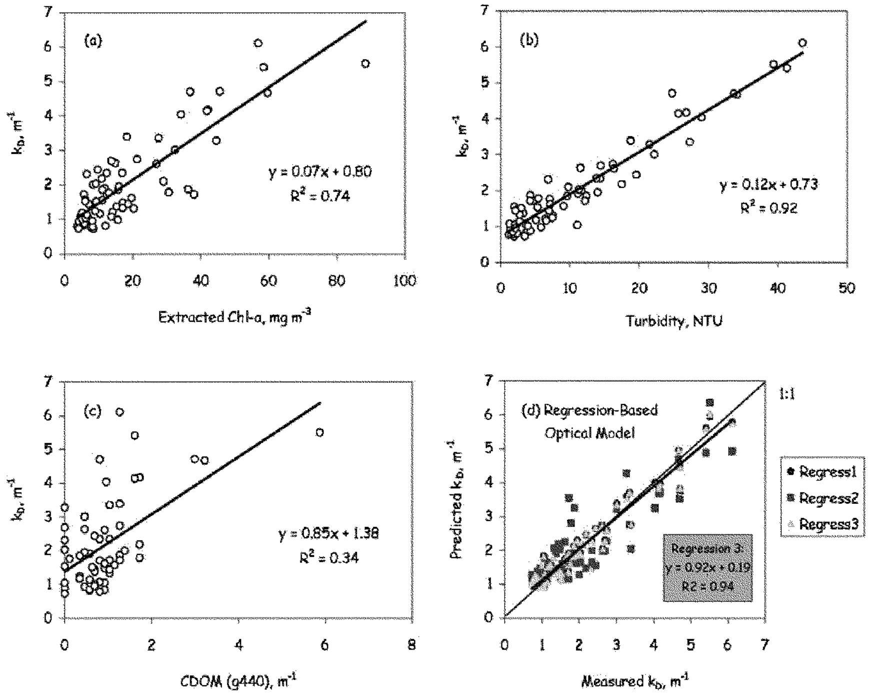


Figure IV.43. Relationship between measured attenuation coefficient for light (k_D) and (a) chlorophyll-a, (b) turbidity, and (c) CDOM, and (d) confirmation of a multiple regression-based model for predicting k_D as a function of these parameters. See Table IV.6 for a definition of the three regressions that were tested.

Table IV.6. Multiple linear regression models for predicting light attenuation as a function of water quality parameters.

Model	Equation	r^2
Regress1	y = 0.71 + 0.022*Chl + 0.089*NTU - 0.032*CDOM	0.94
Regress2	y = 0.98 + 0.075*Chl - 0.0013*TSS - 0.18*CDOM	0.76
Regress3	y = 0.71 + 0.02*Chl + 0.09*NTU	0.94

The resulting regression for k_D (Regress3 in Table IV.6) was combined with the 2005 and 2006 times series data from Broad Bay to estimate the average k_D in the system (1.57 m^{-1}). Using Beer's Law, this value translates into a depth at which 20% of surface irradiance remains of 1.02 m. The 20% light level is generally the minimum light requirement for SAV survival in the polyhaline Chesapeake (Dennison et al., 1993; Kemp et al., 2004). Using the bathymetry from Wang et al.'s hydrodynamic-water quality model, only a thin area of bottom around the shoreline of Broad Bay receives enough light to support SAV, in marked agreement with the observed long-term SAV distribution as reported by VIMS (Figure IV.44). The shoreline along the northeast quadrant of Broad Bay which appears to have enough light but no SAV historically has in fact supported ephemeral *Ruppia maritima* beds, although sediments are likely too sandy for eelgrass.

While results from the 2007-08 time series and metabolic measurements are still being analyzed, a typical P-I curve is shown in Figure IV.45. Water column production increased rapidly from negative values in the dark (i.e., net respiration) and saturated at high light levels. Data will be used to develop a metabolic budget for the entire Lynnhaven system, assess its net metabolic balance, and assess water column vs. sediment dominance of metabolism.

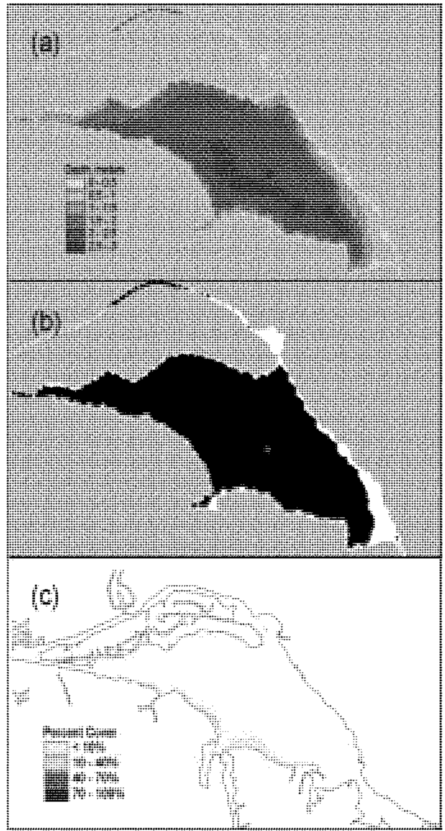


Figure IV.44. Calculation of potential SAV habitat in Broad Bay from (a) bathymetry and *in situ* time series sensors (red point). (b) Area of Broad Bay receiving greater than 20% of incident irradiance on average (white). (c) Long term average SAV cover in Broad Bay, 1992-2003, based on VIMS SAV monitoring program data.

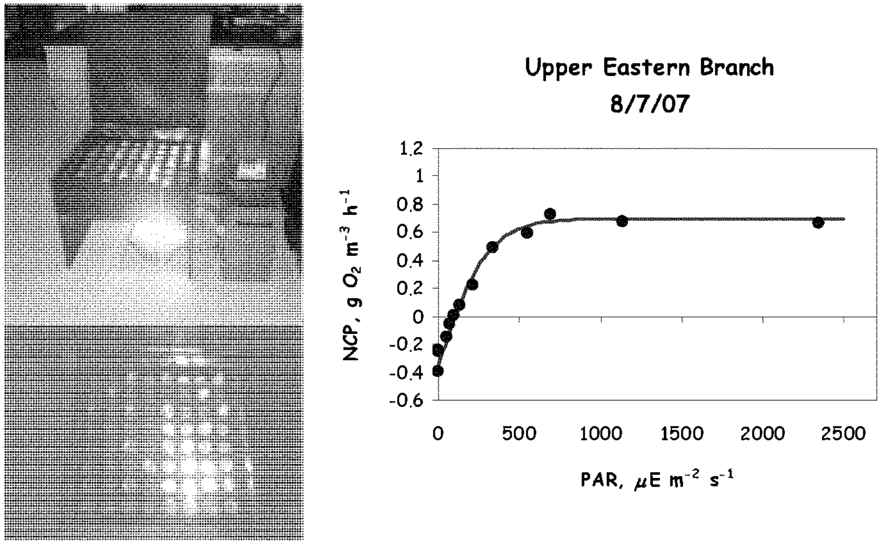


Figure IV.45. Experimental setup (light gradient box) for P-I measurements in 2007-08 and a typical result (blue circles) with a statistically-fit regression (red line). Photosynthesis is expressed as net community production (NCP). Irradiance is expressed as photosynthetically active radiation (PAR).

CHAPTER V. MODEL CALIBRATION

The hydrodynamic and water quality models applied to the Lynnhaven River system were developed using the framework outlined in Chapter III. The calibration is a process by which the performance parameters are constrained by comparing with the field measured observations. For example, the bottom friction parameters were adjusted during the calibration process. A calibration assures that the model will produce results that meet or exceed some defined criteria with a specified degree of confidence. The hydrodynamic model was calibrated with observed surface elevations and velocities using historical data and VIMS hydrodynamic survey data collected in November 2005. The water quality model was calibrated using the 2006 DEQ data and validated over the years 2004 and 2005, during which period both the freshwater discharge and the non-point source loading data were provided by the HSPF watershed model developed for the Lynnhaven by URS Corporation.

V-1 Calibration of the Hydrodynamic Model

The model calibration for the Lynnhaven River used NOAA historical tide data of the late 1970s, NOAA tide prediction data at locations in both the Eastern and Western branches, and short-term velocity measurements taken in the Broad Bay branch in 2003, providing an early view of the model's ability to reproduce the system's hydrodynamics. However, VIMS later decided to conduct a systematic, high-frequency hydrodynamic survey, measuring water elevations inside the inlet synoptically with representative currents and salinities in each branch as well as outside of the Inlet (see Section IV-2-A for a full description of the VIMS Lynnhaven hydrodynamic survey). With these data in hand, validation then consisted of a real-time simulation of the prototype condition for the period November 1 to November 30, 2005. The validation of the hydrodynamic model is described in Chapter VI.

V-1-1 Boundary conditions

For the application of the UnTRIM hydrodynamic model to the Lynnhaven, it was necessary to specify both downstream and upstream boundary conditions. The downstream boundary conditions consisted of specifications of time series of surface elevation and salinity along the row of grid cells at the northern extent of the model grid outside of the Inlet, as shown in Figure V.1. These data were measured at the NOAA facility at the nearby Chesapeake Bay Bridge Tunnel (CBBT), and the surface elevation boundary specification was adjusted for phase by comparing the CBBT record with that from the Kiptopeke primary NOAA station on the Eastern Shore.

Of the 3 Lynnhaven branches, only the Eastern Branch extends beyond the terminus of the watershed region discussed earlier in Section III-5. Therefore, specification of the upstream boundary condition of surface elevation was based on time series of surface elevations recorded at Creeds, VA (i.e., connecting to the southeastern end of the Eastern Branch).

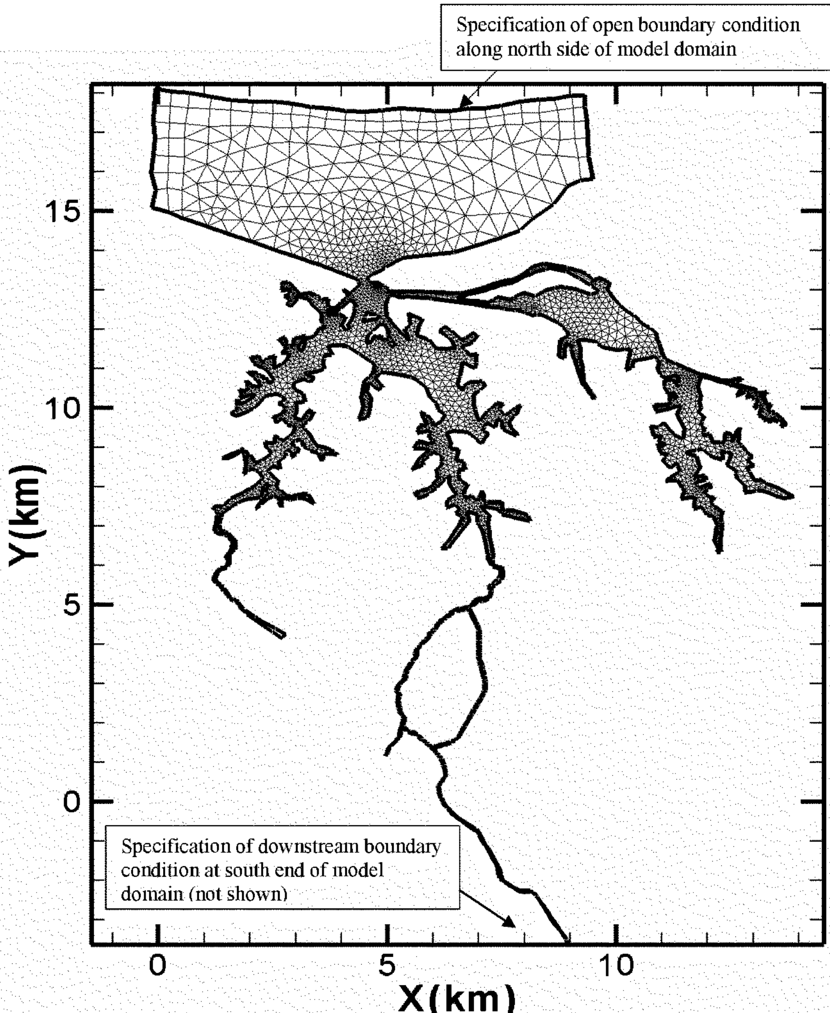


Figure V.1. Locations of boundary condition specifications for Lynnhaven River models

However, the period of measurement of surface elevation at Creeds, VA (2006) differed from the period required for calibration. In the upstream areas of the Eastern Branch, the flow direction is controlled by wind direction as well as tide. For that reason, VIMS performed a correlation between time series of the 2006 CBBT high-frequency wind and the 2006 Creeds, VA surface elevations. The results of this correlation are shown in Figure V.2. Using a relationship based on this correlation, it was then possible to generate a water surface time series specification for the upstream boundary condition of the model at Creeds, VA. An example of the estimated upstream boundary condition is shown in Figure V.3.

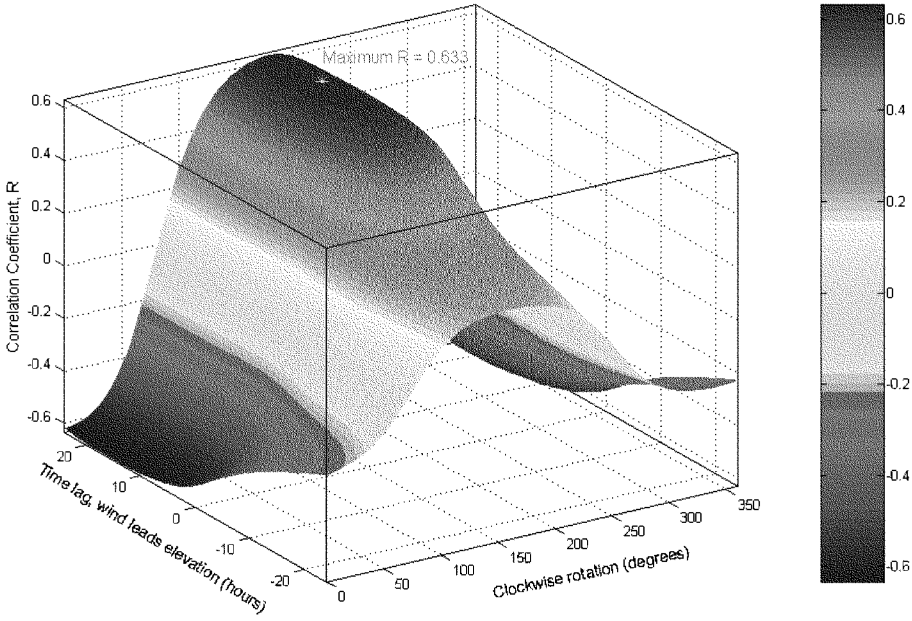


Figure V.2. Correlation of CBBT wind speed with Creeds, VA surface elevation.

V-1-2 External loading

There are no USGS gauges recording freshwater inflow to any of the Lynnhaven branches. For this reason, the VIMS hydrodynamic model was entirely dependent upon the URS watershed model for its freshwater discharge inputs. As discussed in Section III-5, the URS model included hourly freshwater discharge values at each catchment site along with its non-point source loadings.

V-1-3 Calibration for tidal elevation

The astronomical tide accounts for about 80 % of the energy of water surface fluctuations in the Lynnhaven River system. Therefore an accurate reproduction of the tidal wave propagation in the Lynnhaven River is of the utmost importance. Furthermore, once the model is calibrated with respect to astronomical tide, a minimum of additional adjustment is required for calibrations of surface elevation and current velocity.

Preliminary testing of the UnTRIM capability to simulate the propagation of tide was performed prior to the inception of the project, and a thorough search for historical tide data in the Lynnhaven led to a set of 6 stations spanning from outside the Inlet through

Broad Bay and lastly Linkhorn Bay. The locations of these stations are shown in Figure V.4. Measurements at these 6 stations occurred in the late 1970s, but they were synoptic! Tidal propagation in an estuary is controlled by river geometry and frictional dissipation of energy. With river geometry and average tidal range at the open boundary given, we used the distribution of tidal range as a function of distance along the Broad Bay/Linkhorn Bay to calibrate against the roughness height, the model parameter for bottom friction. Figure V.5 shows the comparison of both amplitudes and phase lags of modeled and measured values of the primary tidal constituent (i.e., M_2) at Stations T2 through T6.

The top panel of Figure V.5 shows that dampening of the M_2 tidal amplitude from approximately 0.35 m at the Inlet to approximately 0.18 m at the head of Linkhorn Bay. It can be seen in Figure V.5 that the modeled vs. measured comparison of amplitude is within 2 cm at all 6 stations.

The lower panel of Figure V.5 shows a tidal phase lag of approximately 2.5 hours moving from the Inlet to the head of Linkhorn Bay. The modeled vs. measured phase difference is within a few minutes at all 6 stations.

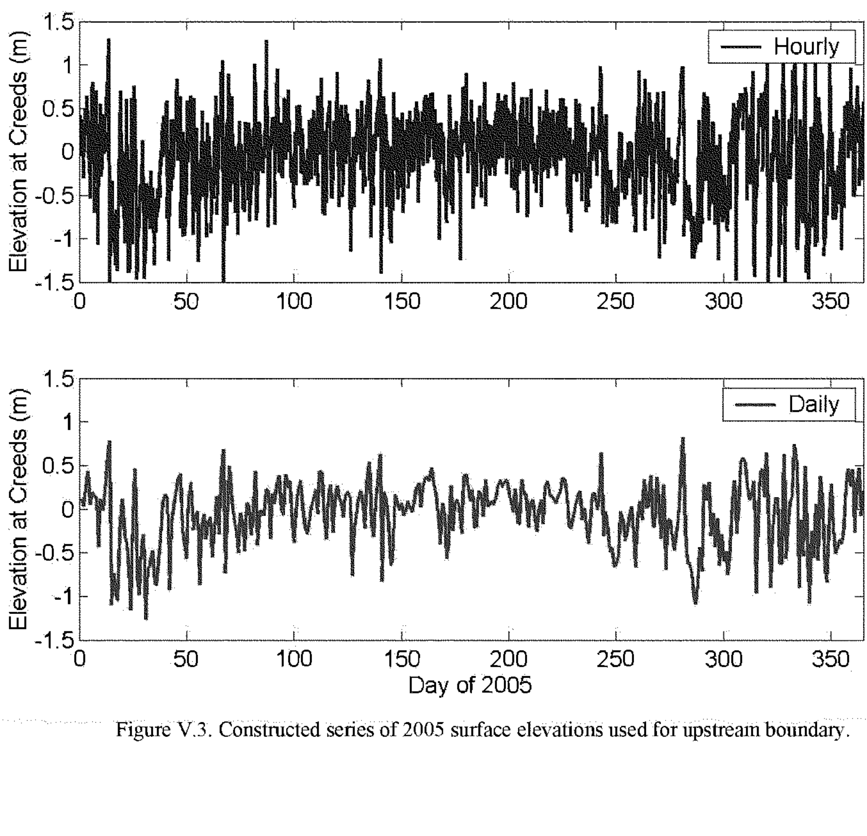


Figure V.3. Constructed series of 2005 surface elevations used for upstream boundary.

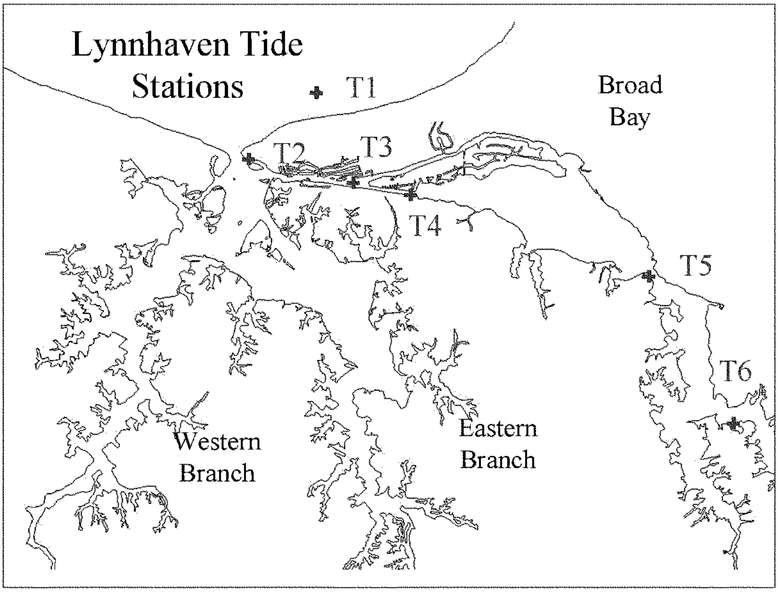


Figure V.4. Locations of NOAA tide stations monitored in the Lynnhaven in the late 1970s.

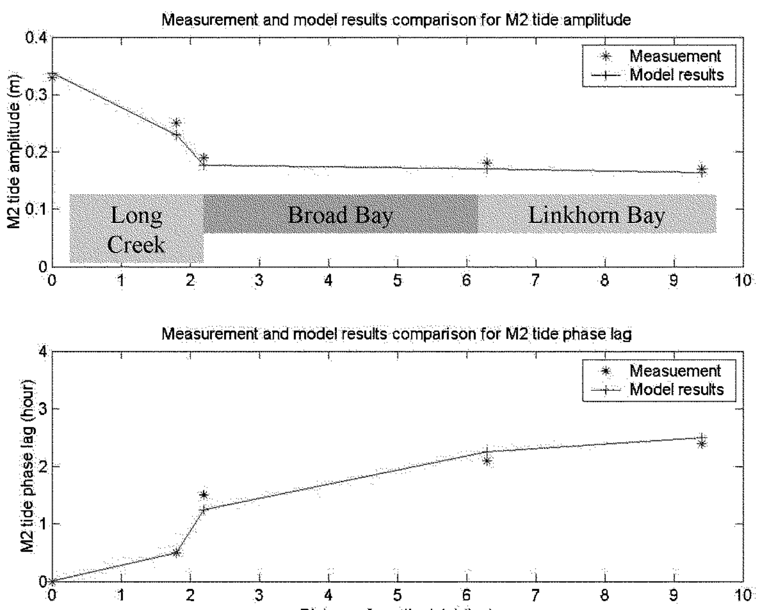


Figure V.5. Comparison of modeled and measured M_2 amplitudes and phases in the Broad Bay/Linkhorn Bay Branch of the Lynnhaven.

Early efforts to calibrate the tides in the Broad Bay/Linkhorn Bay Branch using the CBBT 6-minute tides as an open boundary resulted in good comparisons between prediction of the UnTRIM model and the 1977 NOAA observed tides. Real-time comparisons at Stations T2 through T6 are shown in Figure V.6 below.

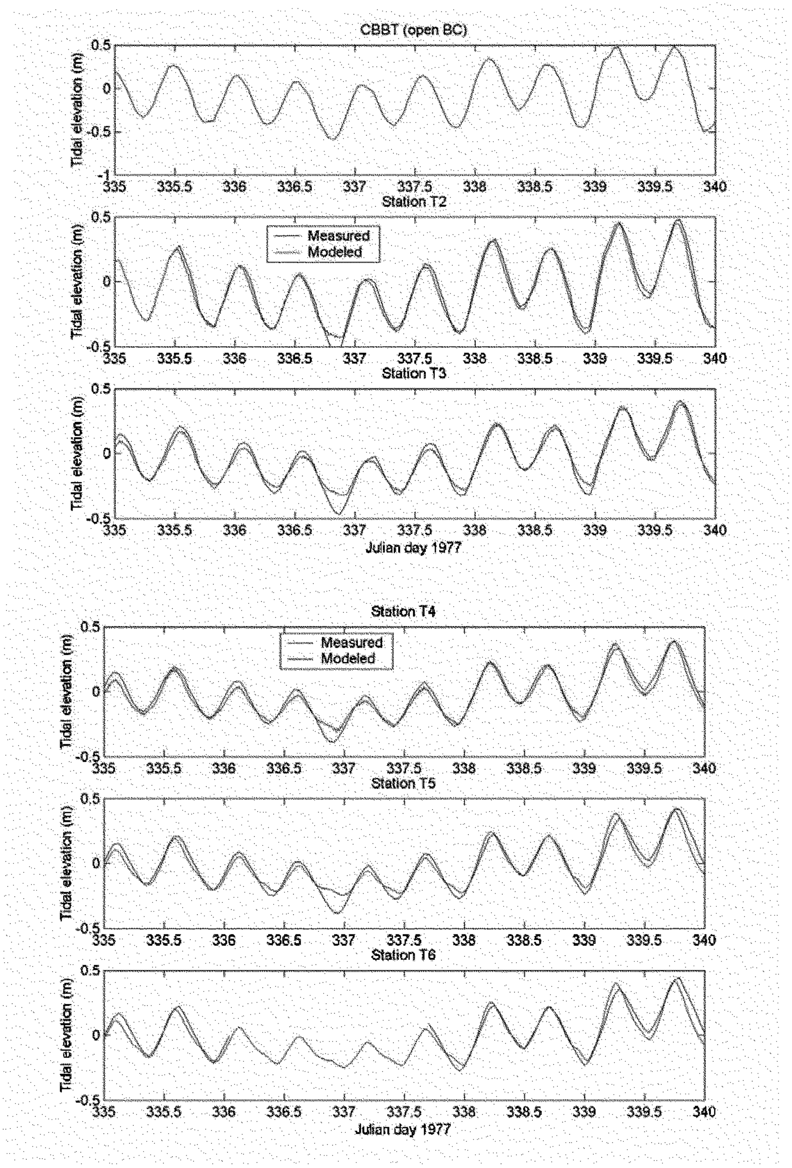


Figure V.6. Real-time comparisons of UnTRIM predictions and NOAA water surface observations.

Table V.1. UnTRIM Modeled Tide Predictions versus Tide Table Predictions in Lynnhaven River Eastern and Western Branches.

Station		**Tide Range (m)**	**High tide phase (minutes later than Inlet)**	**Low tide phase (minutes later than Inlet)**
Bayville Creek (Western Br.)	Tide Tables	0.518	59	97
	Model Results	0.518	60	99
Buchanan Creek (Western Br.)	Tide Tables	0.579	69	105
	Model Results	0.578	63	115
Brown Cove (Eastern Br.)	Tide Tables	0.518	55	97
	Model Results	0.554	45	78

Whereas no historical data could be found in either the Western or Eastern Branches, the published NOAA Tide Tables did provide predictions at 2 locations in the Western Branch (Bayville Creek and Buchanan Creek) and 1 location in the Eastern Branch (Brown Cove) for both tidal range and phase lag from the Inlet. These predictions were compared with results from the model when driven by average tidal range with no discharge or wind specifications, and are shown in Table V.1.

V-1-4 Calibration for velocity

In conjunction with early attempts to calibrate the model for tide, 2 locations were measured for velocity in October, 2003. ADCP instruments were deployed at 2 locations bounding the Long Creek portion of Broad Bay, as shown in Figure V.7 below.

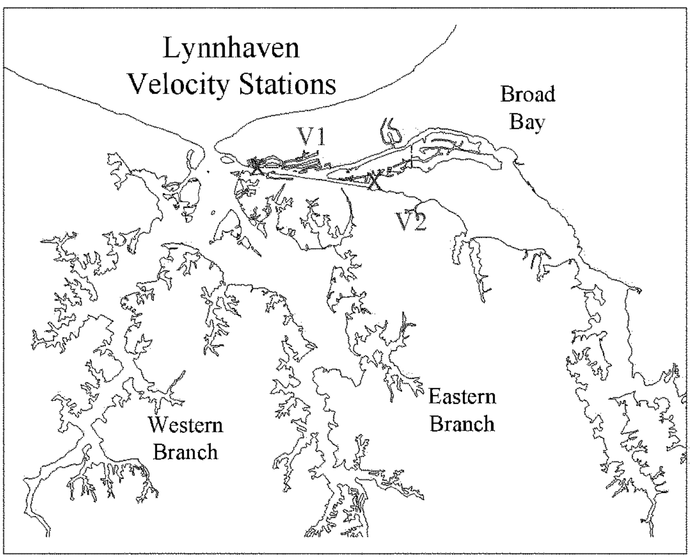


Figure V.7. Locations of Lynnhaven Velocity ADCP Stations, October 2003.

These ADCP measurements were high-frequency (measurements every 60 seconds). Whereas the deployments were of short duration (less than 2 days), they were sufficient in length to confirm the predictive capability of the UnTRIM model for velocity. The comparisons of measured and modeled velocities are shown in Figures V.8 and V.9, respectively, for Stations V1 and V2.

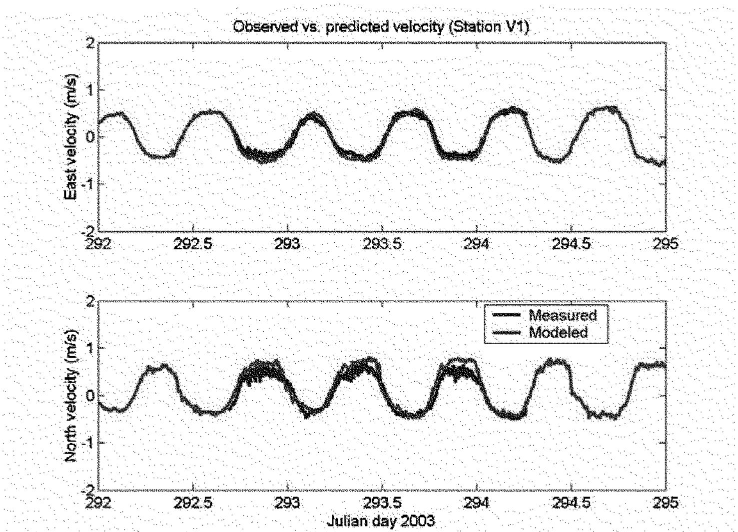


Figure V.8. East-west and north-south components of measured versus modeled velocity at Station V1 of Long Creek, Lynnhaven.

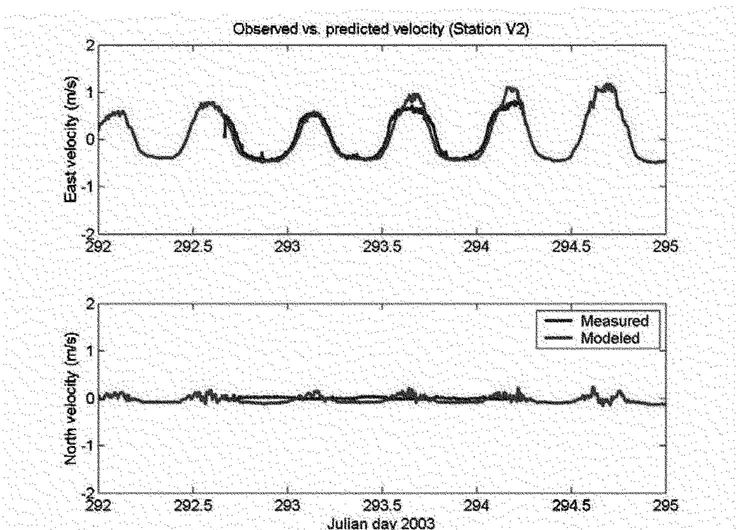


Figure V.9. East-west and north-south components of measured versus modeled velocity at Station V2 of Long Creek, Lynnhaven.

V-1-5 Calibration for salinity

In an estuary, freshwater originating from inland river sources encounters the salt water coming from the ocean to produce the longitudinal salinity gradient. The baroclinic pressure gradient generated from the fresh water at the upstream of the estuary and the salt water at the downstream then serves as the major driving force for the gravitational circulation, in which the freshwater flows seaward while the salt water flows landward. When freshwater overlays salt water, the vertical profile of salinity exhibits stratification as a result of the density difference from surface to bottom. The turbulent mixing induced by forces such as tide, wind, surface waves, internal waves and internal current shear, on the other hand, tends to homogenize property gradients in the water column both in the vertical and the horizontal direction. This turbulent activity thus counter-acts the stratification produced by the buoyancy forces.

In order to calibrate salinity predicted by the UnTRIM hydrodynamic model, comparisons between measurements and model predictions were made at all 16 VA-DEQ stations monitored every other month in the Lynnhaven River throughout calendar year 2006. The locations of these stations are shown below in Figure V.10.

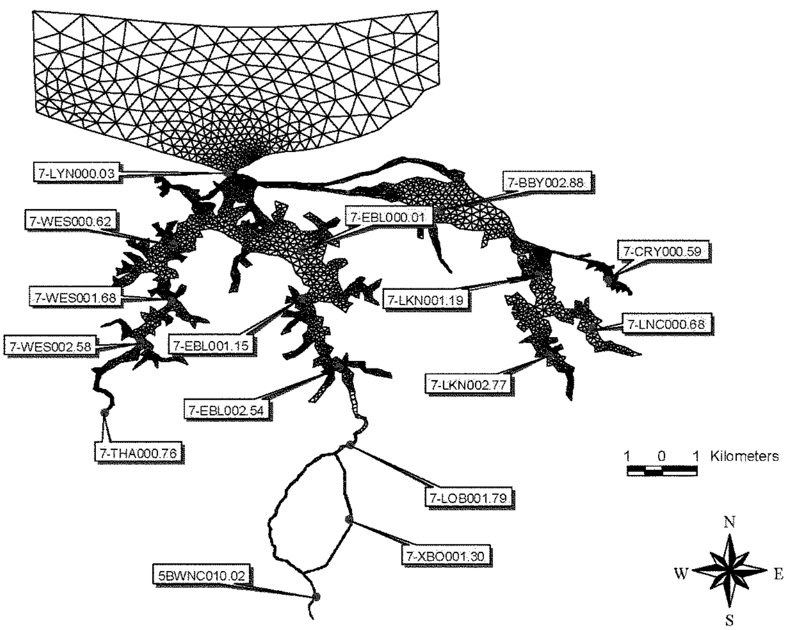


Figure V.10. Locations of Lynnhaven DEQ stations used to compare measured and modeled salinity, temperature, and water quality parameters.

Each estuary has its own shoreline, topography, hydrology, freshwater inputs, and turbulent mixing pattern; the salinity distributions are thus different from one another. By carefully examining the salinity pattern, the characteristics of the estuary can be revealed and classified. Salinity is also an excellent natural tracer due to its conservative property. All in all, salinity is an important parameter for estuarine hydrodynamics and thus is selected to assess the performance of the estuarine hydrodynamic model. In this study, salinity time series and spatial distributions are presented from prototype measurement and compared with the model simulation results.

Measured salinity data also included those made by the VIMS dataflow surveys during this period (please note that the dataflow coverage did not extend to all 16 stations). The modeled vs. measured salinities for 2006 are shown in Figures V.11 through V.13 for comparison at DEQ stations in the Western, Eastern, and Broad Bay /Linkhorn Bay Branches, respectively. It is noted that the model predictions shown in Figures V.11 through V.13 are represented by a gray band bounded by the minimum and maximum daily predictions of salinity at each specified Lynnhaven DEQ station.

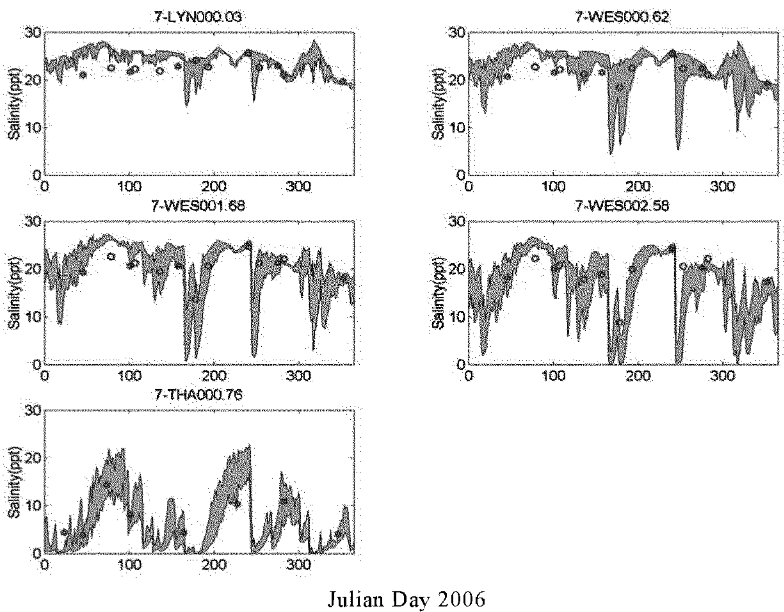


Figure V.11. UnTRIM modeled versus measured salinities at Western Branch DEQ stations for 2006. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.

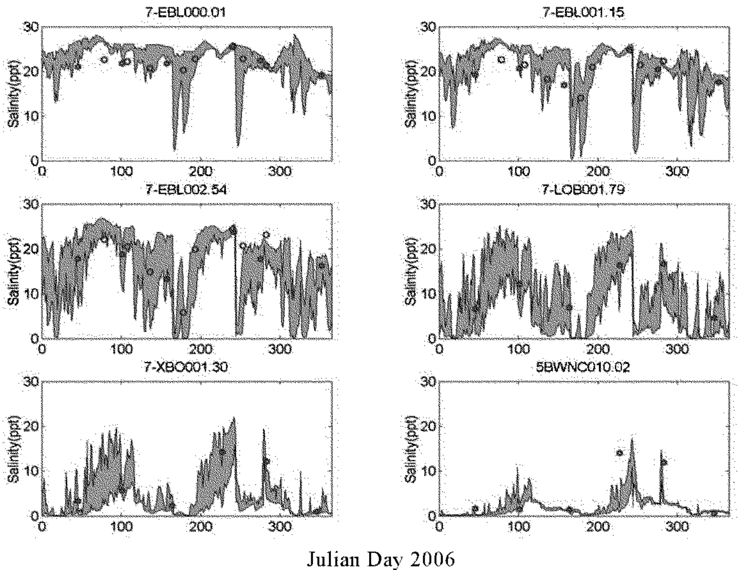


Figure V.12. UnTRIM modeled versus measured salinities at Eastern Branch DEQ stations for 2006. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.

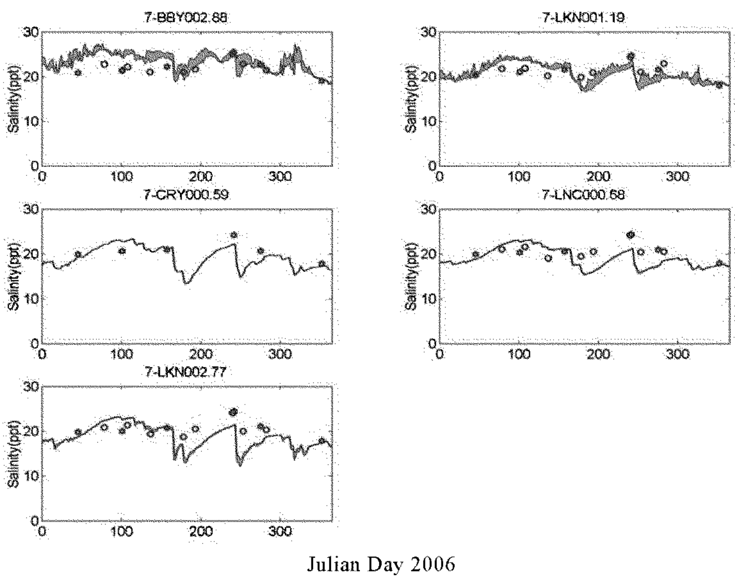


Figure V.13. UnTRIM modeled versus measured salinities at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.

V-1-6 Calibration for temperature

The modeled vs. measured water temperatures for 2006 are shown in Figures V.14 through V.16 for comparison at DEQ stations in the Western, Eastern, and Broad Bay /Linkhorn Bay Branches, respectively.

Modeling of water temperatures is an essential part of the overall water quality modeling effort due to the critical role that temperature plays in the kinetics for all other state variables. As can be seen in Figures V.14 through V.16, water temperatures in the Lynnhaven show a wide seasonal variation from about 5 degrees Celsius in the winter to approximately 25 degrees Celsius in the summer.

Figures V.14 through V.16 show excellent agreement between predicted and observed water temperatures throughout the domain, with some small discrepancies at the most headland stations (e.g., 7-THA000.76 at the head of the Western Branch and 7-LKN002.77 in the upper Linkhorn Bay).

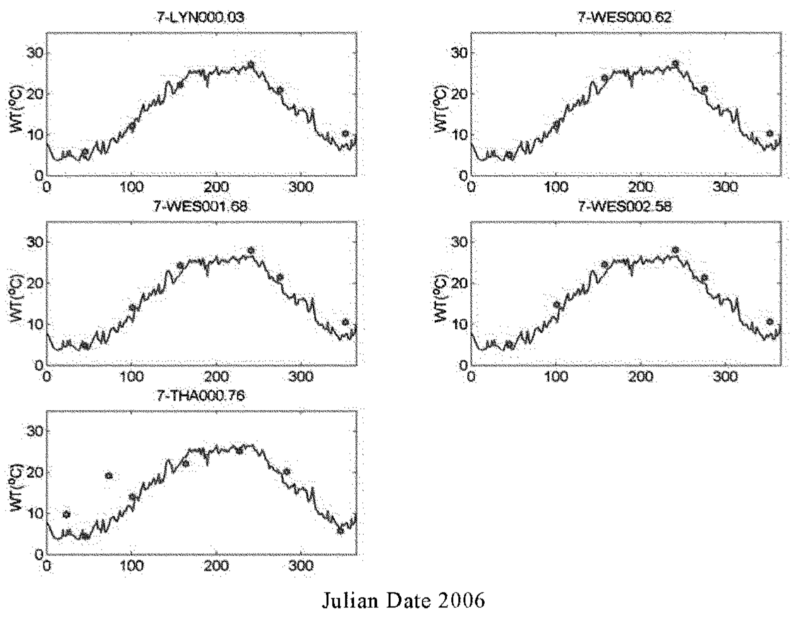


Figure V.14. UnTRIM modeled versus measured temperatures at Western Branch DEQ stations for 2006.

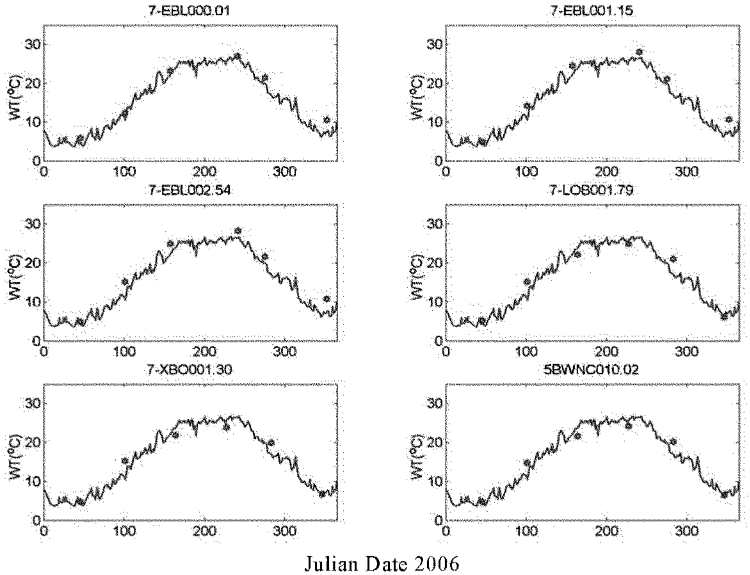


Figure V.15. UnTRIM modeled versus measured temperatures at Eastern Branch DEQ stations for 2006.

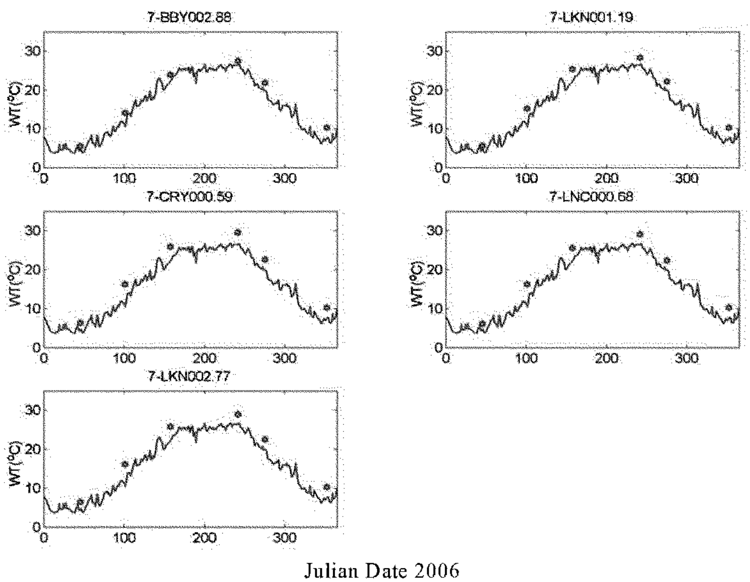


Figure V.16. UnTRIM modeled versus measured temperatures at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

V-2 Calibration of Water Quality Model

The overall objective of the model calibration is to tune the water quality model to the observed data utilizing a set of model coefficients and parameters that are consistent with field measurements and are within the general ranges of values accepted by the modeling community as reported in the literature.

The main steps involved in the calibration of the water quality model are: the appropriate boundary condition has to be chosen, the verified external nutrient loads have to be included, the correct initial condition has to be specified, and the suitable parameter values have to be estimated.

V-2-1 Boundary condition

As was done for the salinity calibration, the water quality monitoring data from Stations CB8.1 and CB8.1E of the Chesapeake Bay Program (CBP) were used for the water quality open boundary condition (Figure V.17). The monthly water quality parameters at both the surface and bottom are available from 1984 to present. Table V.11 shows the parameters measured.

The data from CBP Stations 8.1 and 8.1E are available semi-monthly during the period from spring to fall and monthly during the winter at both the surface and bottom. The middle layers were specified from the linear interpolation between the layers which were measured. The daily values were interpolated between the measured period either semi-monthly or monthly. The present water quality model is configured such that the freshwater discharge and nutrient loadings input are specified as lateral input. The open boundary condition for the hydrodynamic model was forced by the averaged measured tide of the NOAA tidal station at the Chesapeake Bay Bridge Tunnel.

V-2-2 External loading

There is no point source input into the Lynnhaven River. The nonpoint nutrient loadings from the watershed discharged to the Lynnhaven River were obtained from the watershed model developed by URS Corporation of Virginia Beach (see Chapter III, Section III-5). Nonpoint source loads enter the water quality model through specification of the loading at model grid cells adjacent to the land. The procedure involves mapping of the hydrodynamic model grid with watershed catchment areas adjacent to the receiving waters. These nonpoint source inputs are specified at the surface of the model cell at the location of discharge. The external nutrient loads also include the atmospheric loads that are generated by the watershed model and are specified at each surface cell of the model. The time increment for loading input from the watershed model is hourly.

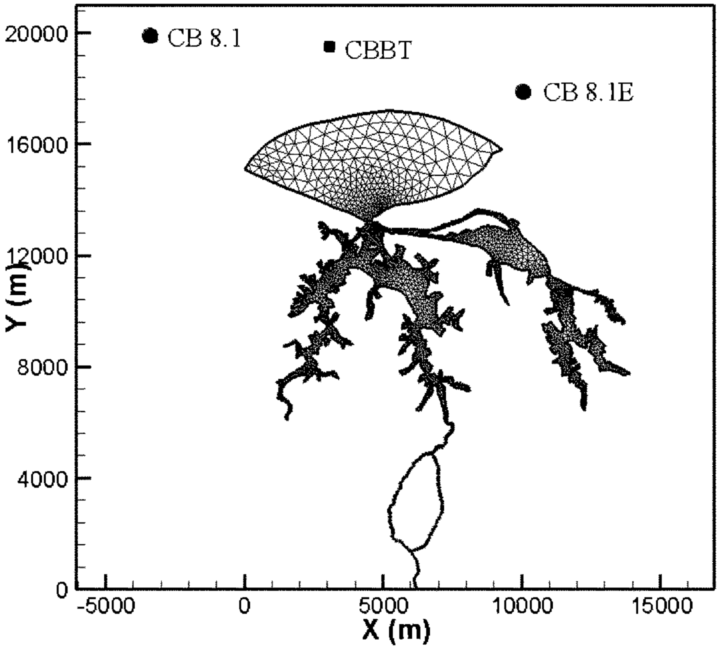


Figure V.17. Locations of CBP Stations CB8.1 and CB8.1E to the northeast and northwest of Lynnhaven River model domain (from Li (2006)).

V-2-3 Initial condition

For an initial simulation, an initial condition was specified as the long-term averaged data measured by DEQ, interpolated spatially. Within the Lynnhaven, the initial condition for each cell was specified through linear interpolation between two adjacent DEQ stations. Since only surface water data are available, the same value was specified for each layer vertically for those cells. Outside of the Lynnhaven, the initial condition was specified based on the linear interpolation between DEQ Station 7-LYN000.03 and CBP Station CB8.1. Upon attaining dynamic equilibrium, the values of all computed model cell output from prior model results were used to specify a suitable initial condition.

V-2-4 Estimation of parameters

Most of the parameters in the CE-QUAL-ICM water quality model were adopted from the default parameters for the Chesapeake Bay (Cerco and Cole, 1994). The parameters used in the water column of this study are listed in Tables V.4 to V.9. The modification of parameters depended on the comparison with measured data or unique features of the Lynnhaven. The remaining parameters used in the sediment flux are listed in Table V.10.

Table V.2. Model state variables in the eutrophication water quality model

Parameter	symbol
Temperature	T
Salinity	S
Total Suspended Solids	TSS
Cyanobacteria	B_c
Diatoms	B_d
Green Algae	B_g
Refractory Particulate Organic Carbon	RPOC
Labile Particulate Organic Carbon	LPOC
Dissolved Organic Carbon	DOC
Refractory Particulate Organic Nitrogen	RPON
Labile Particulate Organic Nitrogen	LPON
Dissolved Organic Nitrogen	DON
Ammonium Nitrogen	NH_4
Nitrate+nitrite Nitrogen	NO_3
Refractory Particulate Organic Phosphorus	RPOP
Labile Particulate Organic Phosphorus	LPOP
Dissolved Organic Phosphorus	DOP
Total Phosphate	PO_4t
Particulate Biogenic Silica	SU
Available Silica	SA
Chemical Oxygen Demand	COD
Dissolved Oxygen	DO

Table V.3. Model state variables and fluxes in the benthic sediment flux model

Parameters
particulate organic carbon in Layer 2 (G_1, G_2 and G_3 classes)
particulate organic nitrogen in Layer 2 (G_1, G_2 and G_3 classes)
particulate organic phosphorus in Layer 2 (G_1, G_2 and G_3 classes)
particulate biogenic silica in Layer 2
sulfide (salt water) or methane (fresh water) in Layers 1 and 2
ammonium nitrogen in Layers 1 and 2
nitrate nitrogen in Layers 1 and 2
phosphate phosphorus in Layers 1 and 2
available silica in Layers 1 and 2
ammonium nitrogen flux
nitrate nitrogen flux
phosphate flux
silica flux
sediment oxygen demand
release of chemical oxygen demand
sediment temperature
benthic microalgae

Table V.4. Parameters related to algae in the water column

parameter	description	value	units
PM_c	maximum growth rate of algae group 1	250	$g\ C\ g^{-1}\ Chl\ d^{-1}$
PM_d	maximum growth rate of algae group 2	300	$g\ C\ g^{-1}\ Chl\ d^{-1}$
PM_g	maximum growth rate of algae group 3	300	$g\ C\ g^{-1}\ Chl\ d^{-1}$
KHN_x	half-saturation constant of N uptake by algae	0.01	$g\ N\ m^{-3}$
KHP_x	half-saturation constant of P uptake by algae	0.001	$g\ P\ m^{-3}$
KHS	half-saturation constant of Si uptake by diatoms	0.05	$g\ Si\ m^{-3}$
KHRx	half-saturation constant of DO for algal excretion of DOC	0.5	$g\ O_2\ m^{-3}$
α_c	initial slope of production vs. irradiance relationship for algal group 1	8	$g\ C\ g^{-1}\ Chl\ (E\ m^{-2})^{-1}$
α_d	initial slope of production vs. irradiance relationship for algal group 2	8	$g\ C\ g^{-1}\ Chl\ (E\ m^{-2})^{-1}$
α_g	initial slope of production vs. irradiance relationship for algal group 3	8	$g\ C\ g^{-1}\ Chl\ (E\ m^{-2})^{-1}$
a_1	background light attenuation coefficient	0.735	m^{-1}
a_2	light attenuation coefficient due to total suspended solid	0.018	m^2 per g TSS
a_3	light attenuation coefficient due to algae	0.06	m^2 per mg CHL
$CCHL_x$	C-to-CHL ratio in algae	60.0	g C per g CHL
TM_c	optimum T for algal group 1 growth	29.0	°C
TM_d	optimum T for algal group 2 growth	16.0	°C
TM_g	optimum T for algal group 3 growth	25.0	°C
$KTG1_c$	effect of T below optimum T on algal Group 1 growth	0.006	$°C^{-2}$
$KTG2_c$	effect of T above optimum T on algal Group 1 growth	0.006	$°C^{-2}$
$KTG1_d$	effect of T below optimum T on algal Group 2 growth	0.004	$°C^{-2}$
$KTG2_d$	effect of T above optimum T on algal Group 2 growth	0.006	$°C^{-2}$
$KTG1_g$	effect of T below optimum T on algal Group 3 growth	0.012	$°C^{-2}$
$KTG2_g$	effect of T above optimum T on algal Group 3 growth	0.007	$°C^{-2}$
BMR_c	basal metabolism rate of algae group 1 at reference T	0.02	day^{-1}
BMR_d	basal metabolism rate of algae group 2 at reference T	0.04	day^{-1}
BMR_g	basal metabolism rate of algae group 3 at reference T	0.02	day^{-1}
PRR_c	predation rate of algae group 1 at reference T	0.02	day^{-1}
PRR_d	predation rate of algae group 2 at reference T	0.15	day^{-1}
PRR_g	predation rate of algae group 3 at reference T	0.25	day^{-1}
KTB_x	effect of T on basal metabolism of algae	0.069	$°C^{-1}$
TR_x	reference T for basal metabolism of algae	20.0	°C
WS_c	settling velocity for algal group 1 0.1	$m\ day^{-1}$	

Table V.4 (cont'd)

WS_d	settling velocity for algal group 2	0.2	m day^{-1}
WS_g	settling velocity for algal group 3	0.1	m day^{-1}

Table V.5. Parameters related to organic carbon in the water column

Parameters	description	value	units
FCRP	fraction of predated algal C produced as RPOC	0.20	none
FCLP	fraction of predated algal C produced as LPOC	0.65	none
FCDP	fraction of predated algal C produced as DOC	0.15	none
FCD_x	fraction of metabolized C by algae produced as DOC	0.0	none
KHR_x	half-saturation constant of DO for algal excretion of DOC	0.5	g O_2 m^{-3}
KHO_{DOC}	half-saturation constant of DO for oxic respiration of DOC	0.5	g O_2 m^{-3}
K_{RC}	minimum respiration rate of RPOC	0.005	day^{-1}
K_{LC}	minimum respiration rate of LPOC	0.075	day^{-1}
K_{DC}	minimum respiration rate of DOC	0.020	day^{-1}
K_{Rcalg}	constant relating respiration of RPOC to algal biomass	0.0	day^{-1} per g C m^{-3}
K_{Lcalg}	constant relating respiration of LPOC to algal biomass	0.0	day^{-1} per g C m^{-3}
K_{Dcalg}	constant relating respiration of DOC to algal biomass	0.0	day^{-1} per g C m^{-3}
KT_{HDR}	effect of T on hydrolysis/ mineralization of POM/DOM	0.069	$°C^{-1}$
KT_{MNL}	effect of T on hydrolysis/ mineralization of POM/DOM	0.069	$°C^{-1}$
TR_{HDR}	reference T for hydrolysis of POM	20.0	°C
TR_{MNL}	reference T for mineralization of DOM	20.0	°C
$KHNDN_N$	half-saturation constant of NO_{23} for denitrification	0.1	g N m^{-3}
AANOX	ratio of denitrification to oxic DOC respiration rate	0.5	none

Table V.6. Parameters related to nitrogen in the water column

Parameters	description	value	units
FNRP	fraction of predated algal N produced as RPON	0.15	none
FNLP	fraction of predated algal N produced as LPON	0.25	none
FNDP	fraction of predated algal N produced as DON	0.20	none
FNIP	fraction of predated algal N produced as NH_4	0.40	none
FNR	fraction of metabolized algal N produced as RPON	0.05	none
FNL	fraction of metabolized algal N produced as LPON	0.20	none
FND	fraction of metabolized algal N produced as DON	0.20	none
FNI	fraction of metabolized algal N produced as NH_4	0.55	none
ANC_{min}	minimum N-to-C ratio in algae	0.135	g N per g C
ANC_{max}	maximum N-to-C ratio in algae	0.20	g N per g C
ANDC	mass of NO_{23}-N consumed per mass DOC oxidized	0.933	g N per g C
K_{RN}	minimum hydrolysis/mineralization rate of RPON	0.005	day^{-1}
K_{LN}	minimum hydrolysis/mineralization rate of LPON	0.075	day^{-1}
K_{DN}	minimum hydrolysis/mineralization rate of DON	0.015	day^{-1}
K_{Rnalg}	constant relating hydrolysis/mineralization of RPON to algal biomass	0.0	day^{-1} per g N m^{-3}
K_{Lnalg}	constant relating hydrolysis/mineralization of LPON to algal biomass	0.0	day^{-1} per g N m^{-3}
K_{Dnalg}	constant relating hydrolysis/mineralization of DON to algal biomass	0.0	day^{-1} per g N m^{-3}
$KHDO_{NIT}$	half-saturation constant of DO for nitrification	1.0	g O_2 m^{-3}
KHN_{NIT}	half-saturation constant of NH_4 for nitrification	1.0	g N m^{-3}
NT_M	maximum nitrification at optimum T	0.007	day^{-1}
KT_{NT1}	effect of T below optimum T on nitrification rate	0.0045	°C^{-2}
KT_{NT1}	effect of T above optimum T on nitrification rate	0.0045	°C^{-2}
TM_{NT}	optimum T for nitrification rate	27.0	°C

Table V.7. Parameters related to phosphorus in the water column

Parameter	description	value	units
FPRP	fraction of predated algal P produced as RPOP	0.03	none
FPLP	fraction of predated algal P produced as LPOP	0.07	none
FPDP	fraction of predated algal P produced as DOP	0.40	none
FPIP	fraction of predated algal P produced as DIP	0.50	none
FPR_x	fraction of metabolized P by algae produced as RPOP	0.0	none
FPL_x	fraction of metabolized P by algae produced as LPOP	0.0	none
FPD_x	fraction of metabolized P by algae produced DOP	0.25	none
FPI_x	fraction of metabolized P by algae produced DOP	0.75	none
APCMIN	minimum P-to-C ratio in algae	0.0125	g P per g C
APCMAX	maximum P-to-C ratio in algae	0.0175	g P per g C
PO4DMAX	maximum PO4d beyond which APC = APCMAX	0.01	g P m^{-3}
K_{RP}	minimum hydrolysis/mineralization rate of RPOP	0.005	day^{-1}
K_{LP}	minimum hydrolysis/mineralization rate of LPOP	0.075	day^{-1}
K_{DP}	minimum hydrolysis/mineralization rate of DOP	0.1	day^{-1}
K_{Rpalg}	constant relating hydrolysis/ mineralization of RPOP to algal biomass	0.0	day^{-1} per g P m^{-3}
K_{Lpalg}	constant relating hydrolysis/ mineralization of LPOP to algal biomass	0.0	day^{-1} per g P m^{-3}
K_{Dpalg}	constant relating hydrolysis/ mineralization of DOP to algal biomass	0.0	day^{-1} per g P m^{-3}

Table V.8. Parameters related to silica in the water column

Parameter	description	value	units
FSA	fraction of predated diatom Si as SA	0.0	none
ASC_d	Si-to-C ratio in diatoms	0.5	g Si per g C
K_{SU}	dissolution rate of SU at reference T	0.025	day^{-1}
KT_{SUA}	effect of T on dissolution of SU	0.092	$°C^{-1}$
TR_{SUA}	reference T for dissolution of SU	20.0	°C

Table V.9. Parameters related to chemical oxygen demand and dissolved oxygen in the water column

Parameters	description	value	units
KHO_{COD}	half-saturation constant of DO for oxidation of COD	1.5	g O_2 m^{-3}
K_{CD}	oxidation rate of COD at reference temperature	20.0	day^{-1}
KT_{COD}	effect of T on oxidation of COD	0.041	$°C^{-1}$
TR_{COD}	reference T for oxidation of COD	20.0	°C
K_{RDO}	reaeration coefficient	2.4	m day^{-1}
AOCR	mass DO consumed per mass C respired by algae	2.67	g O_2 per g C
AONT	mass DO consumed per mass NH_4-N nitrified	4.33	g O_2 per g N

Table V.10. Parameters used in the sediment flux model

parameter	description	value	units
HSEDALL	depth of sediment	10	cm
DIFFT	heat diffusion coefficient between water column and sediment	0.0018	cm^2 sec^{-1}
SALTSW	salinity for dividing fresh and saltwater for SOD kinetics (sulfide in saltwater or methane in freshwater) and for PO_4 sorption coefficients	1.0	ppt
SALTND	salinity for dividing fresh or saltwater for nitrification/denitrification rates (larger values for freshwater)	1.0	ppt
FRPPH1(1)	fraction of POP in algal group No. 1 routed into G_1 class	0.65	none
FRPPH1(2)	fraction of POP in algal group No. 1 routed into G_2 class	0.255	none
FRPPH1(3)	fraction of POP in algal group No. 1 routed into G_3 class	0.095	none
FRPPH2(1)	fraction of POP in algal group No. 2 routed into G_1 class	0.65	none
FRPPH2(2)	fraction of POP in algal group No. 2 routed into G_2 class	0.255	none
FRPPH2(3)	fraction of POP in algal group No. 2 routed into G_3 class	0.095	none
FRPPH3(1)	fraction of POP in algal group No. 3 routed into G_1 class	0.65	none

Table V.10 (cont'd)

FRPPH3(2)	fraction of POP in algal group No. 3 routed into G_2 class	0.255	none
FRPPH3(3)	fraction of POP in algal group No. 3 routed into G_3 class	0.095	none
FRNPH1(1)	fraction of PON in algal group No. 1 routed into G_1 class	0.65	none
FRNPH1(2)	fraction of PON in algal group No. 1 routed into G_2 class	0.28	none
FRNPH1(3)	fraction of PON in algal group No. 1 routed into G_3 class	0.07	none
FRNPH2(1)	fraction of PON in algal group No. 2 routed into G_1 class	0.65	none
FRNPH2(2)	fraction of PON in algal group No. 2 routed into G_2 class	0.28	none
FRNPH2(3)	fraction of PON in algal group No. 2 routed into G_3 class	0.07	none
FRNPH3(1)	fraction of PON in algal group No. 3 routed into G_1 class	0.65	none
FRNPH3(2)	fraction of PON in algal group No. 3 routed into G_2 class	0.28	none
FRNPH3(3)	fraction of PON in algal group No. 3 routed into G_3 class	0.07	none
FRCPH1(1)	fraction of POC in algal group No. 1 routed into G_1 class	0.65	none
FRCPH1(2)	fraction of POC in algal group No. 1 routed into G_2 class	0.255	none
FRCPH1(3)	fraction of POC in algal group No. 1 routed into G_3 class	0.095	none
FRCPH2(1)	fraction of POC in algal group No. 2 routed into G_1 class	0.65	none
FRCPH2(2)	fraction of POC in algal group No. 2 routed into G_2 class	0.255	none
FRCPH2(3)	fraction of POC in algal group No. 2 routed into G_3 class	0.095	none
FRCPH3(1)	fraction of POC in algal group No. 3 routed into G_1 class	0.65	none
FRCPH3(2)	fraction of POC in algal group No. 3 routed into G_2 class	0.255	none
FRCPH3(3)	fraction of POC in algal group No. 3 routed into G_3 class	0.095	none
KPDIAG(1)	reaction (decay) rates for G_1 class POP at 20°C	0.035	day^{-1}
KPDIAG(2)	reaction (decay) rates for G_2 class POP at 20°C	0.0018	day^{-1}
KPDIAG(3)	reaction (decay) rates for G_3 class POP at 20°C	0.0	day^{-1}
DPTHTA(1)	constant for T adjustment for G_1 class POP decay	1.10	none
DPTHTA(2)	constant for T adjustment for G_2		

Table V.10 (cont'd)

	class POP decay	1.15	none
KNDIAG(1)	reaction (decay) rates for G_1 class PON at 20°C	0.035	day^{-1}
KNDIAG(2)	reaction (decay) rates for G_2 class PON at 20°C	0.0018	day^{-1}
KNDIAG(3)	reaction (decay) rates for G_3 class PON at 20°C	0.0	day^{-1}
DNTHTA(1)	constant for T adjustment for G_1 class PON decay	1.10	none
DNTHTA(2)	constant for T adjustment for G_2 class PON decay	1.15	none
KCDIAG(1)	reaction (decay) rates for G_1 class POC at 20°C	0.035	(day^{-1})
KCDIAG(2)	reaction (decay) rates for G_2 class POC at 20°C	0.0018	(day^{-1})
KCDIAG(3)	reaction (decay) rates for G_3 class POC at 20°C	0.0	(day^{-1})
DCTHTA(1)	constant for T adjustment for G_1 class POC decay	1.10	none
DCTHTA(2)	constant for T adjustment for G_2 class POC decay	1.15	none
KSI	1^{st}-order reaction (dissolution) rate of PSi at 20°C	0.5	day^{-1}
THTASI	constant for T adjustment for PSi dissolution	1.1	none
M1	solid concentrations in Layer 1	0.5	$kg\ l^{-1}$
M2	solid concentrations in Layer 2	0.5	$kg\ l^{-1}$
THTADP	constant for T adjustment for diffusion coefficient for particle mixing	1.117	none
THTADD	constant for T adjustment for diffusion coefficient for dissolved phase	1.08	none
KAPPNH4F	optimum reaction velocity for nitrification in Layer 1 for freshwater	0.20	$m\ day^{-1}$
KAPPNH4S	optimum reaction velocity for nitrification in Layer 1 for saltwater	0.14	$m\ day^{-1}$
THTANH4	constant for T adjustment for nitrification	1.08	none
KMNH4	half-saturation constant of NH_4 for nitrification	1500.0	$mg\ N\ m^{-3}$
KMNH4O2	half-saturation constant of DO for nitrification	1.0	$g\ O_2\ m^{-3}$
PIENH4	partition coefficient for NH_4 in both layers	1.0	$per\ kg\ l^{-1}$
KAPPNO3F	reaction velocity for denitrification in Layer 1 at 20°C for freshwater	0.3	$m\ day^{-1}$
KAPPNO3S	reaction velocity for denitrification		

Table V.10 (cont'd)

	in Layer 1 at 20°C for saltwater	0.125	m day^{-1}
K2NO3	reaction velocity for denitrification in Layer 2 at 20°C	0.25	m day^{-1}
THTANO3	constant for T adjustment for denitrification	1.08	none
KAPPD1	reaction velocity for dissolved H_2S oxidation in Layer 1 at 20°C	0.2	m day^{-1}
KAPPP1	reaction velocity for particulate H_2S oxidation in Layer 1 at 20°C	0.4	m day^{-1}
PIE1S	partition coefficient for H_2S in Layer 1	100.0	per kg l^{-1}
PIE2S	partition coefficient for H_2S in Layer 2	100.0	per kg l^{-1}
THTAPD1	constant for T adjustment for both dissolved & particulate H_2S oxidation	1.08	none
KMHSO2	constant to normalize H_2S oxidation rate for oxygen	4.0	g O_2 m^{-3}
CSISAT	saturation concentration of Si in the pore water	40000.0	mg Si m^{-3}
DPIE1SI	incremental partition coefficient for Si in Layer 1	10.0	per kg l^{-1}
PIE2SI 2	partition coefficient for Si in Layer 2	100.0	per kg l^{-1}
O2CRITSI	critical DO concentration for Layer 1 incremental Si sorption	1.0	g O_2 m^{-3}
KMPSI	half-saturation constant of PSi for Si dissolution	5×10^7	mg Si m^{-3}
JSIDETR	detrital flux of PSi to account for PSi settling to the sediment that is not associated with algal flux of PSi	100.0	mg Si m^{-2} day^{-1}
DPIE1PO4F*	incremental partition coefficient for PO_4 in Layer 1 for freshwater	3000.0	per kg l^{-1}
DPIE1PO4S*	incremental partition coefficient for PO_4 in Layer 1 for saltwater	300.0	per kg l^{-1}
PIE2PO4*	partition coefficient for PO_4 in Layer 2	100.0	per kg l^{-1}
O2CRIT	critical DO concentration for Layer 1 incremental PO_4 sorption	2.0	g O_2 m^{-3}
KMO2DP	half-saturation constant of DO for particle mixing	4.0	g O_2 m^{-3}
TEMPBEN	temperature at which benthic stress accumulation is reset to zero	10.0	°C
KBENSTR	1^{st}-order decay rate for benthic stress	0.03	day^{-1}
KLBNTH	ratio of bio-irrigation to bioturbation	0.0	none
DPMIN	minimum diffusion coefficient for particle mixing	3×10^{-6}	m^2 day^{-1}
KAPPCH4	reaction velocity for dissolved CH_4 oxidation in Layer 1 at 20°C	0.2	m day^{-1}

Table V.10 (con't)

THTACH4	constant for T adjustment for dissolved CH_4 oxidation	1.08	none
VSED	net burial (sedimentation) rate	0.25	cm yr^{-1}
VPMIX	diffusion coefficient for particle mixing	1.2×10^{-4}	m^2 day^{-1}
VDMIX	diffusion coefficient in pore water	0.001	m^2 day^{-1}
WSCNET	net settling velocity for algal group 1	0.1	m day^{-1}
WSDNET	net settling velocity for algal group 2	0.3	m day^{-1}
WSGNET	net settling velocity for algal group 3	0.1	m day^{-1}

Table V.11. Water quality parameters in CBP monitoring data

Parameters	**symbol**	**units**
temperature	T	degrees C
salinity	S	ppt
dissolved oxygen	DO	mg/l
chlorophyll-a	CHL	μg/l
total suspended solids	TSS	mg/l
secchi depth		m
particulate carbon	PC	mg/l
dissolved organic carbon	DOC	mg/l
particulate nitrogen	PN	mg/l
total dissolved nitrogen	TDN	mg/l
ammonium nitrogen	NH_4	mg/l
nitrate+nitrite nitrogen	NO_3	mg/l
particulate phosphorus	PP	mg/l
total dissolved phosphorus	TDP	mg/l
dissolved phosphate	PO_4d	mg/l
particulate inorganic phosphorus	PIP	mg/l
particulate biogenic silica	SU	mg/l
dissolved silica	SA	mg/l

V-2-5 Model Calibration Results

Calibration of the water quality model is shown by the comparison of time series plots of selected water quality parameters with DEQ observations at all 16 DEQ stations spanning the Lynnhaven River. The locations of the stations are shown in Figure V.18. To facilitate the comparison, stations of each Lynnhaven River branch are clustered in the figures comparing observed versus predicted values of each parameter for stations of that branch.

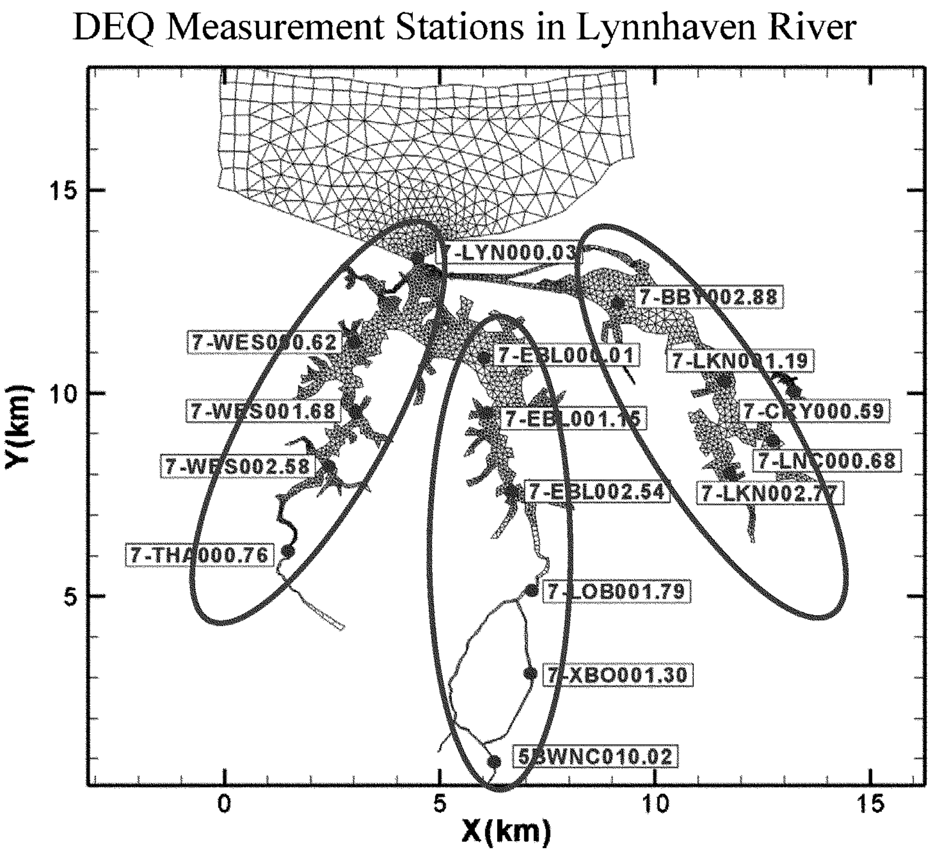


Figure V.18. Grouping of Lynnhaven DEQ stations by branch, as used in displaying CE-QUAL-ICM water quality model calibration results.

For the calibration, comparisons at each station were made for the full calendar year 2006. These comparisons included the primary parameters of dissolved oxygen, chlorophyll-a, total Kjeldahl nitrogen (TKN), ammonium, nitrate-nitrite, total phosphorus, and ortho phosphorus. For validation of the model, these same comparisons were also made for the full calendar years 2004 and 2005 and are presented in Chapter VI.

The quantification of the model's overall ability to reproduce the observed data at these stations, as measured by statistical analysis, is presented later in this section. For the analysis on each water quality state variable, the differences of predicted and observed values for all 16 Lynnhaven DEQ stations were included.

A. Western Branch DEQ stations calibration results

Water quality model calibration results for Western Branch DEQ stations for 2006 are shown in Figures V.19 through V.25. In all figures comparing modeled and measured water quality parameters, the model predictions are represented as a gray band bounded by daily minimum and maximum predictions.

Results for dissolved oxygen are shown in Figure V.19. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen reasonably well, with some discrepancy at the upstream Thalia Creek station, the only Western Branch DEQ station where DO values fall below 5 mg/l. Figure V.20 presents the predicted versus observed comparisons for chlorophyll-a, catching the trend for the downstream stations, but showing slight under-predictions. Figure V.21 shows that the model captures TKN values well for all Western Branch DEQ stations. The predictions of ammonium and nitrate-nitrite shown in Figures V.22 and V.23, respectively, have some large diurnal fluctuations, but observed values primarily fall within these ranges. Figures V.24 and V.25 show that both total phosphorus and ortho phosphorus measurements are captured reasonably well at all stations. An inspection of Figures V.19 through V.25 shows the gradual decrease of dissolved oxygen and increases of both chlorophyll-a and nutrients in moving from the Inlet upstream to Thalia Creek.

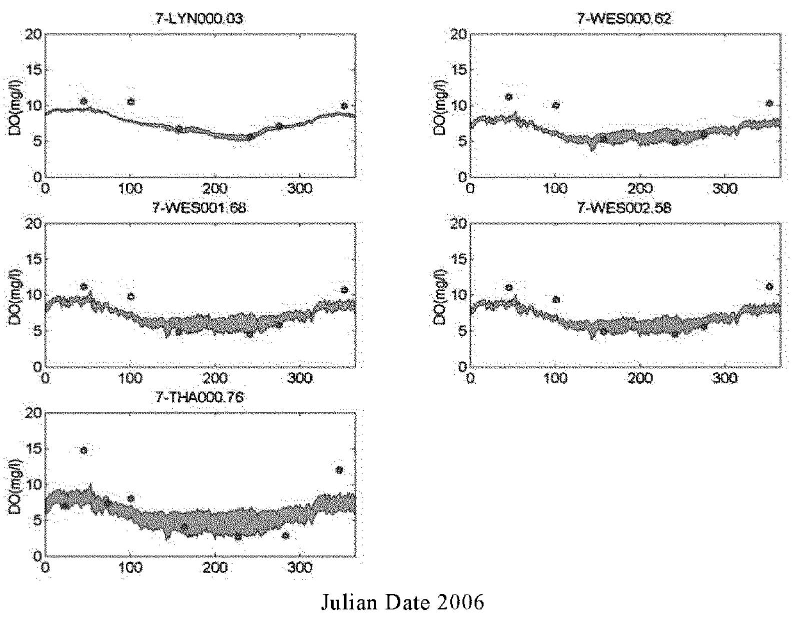


Figure V.19. Predicted vs. observed DO at Western Branch DEQ stations for 2006.

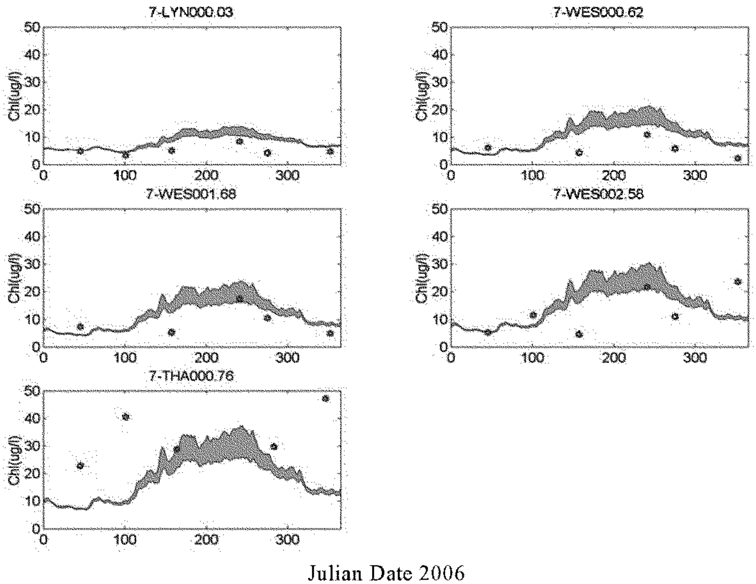


Figure V.20. Predicted vs. observed chlorophyll-a at Western Branch DEQ stations for 2006.

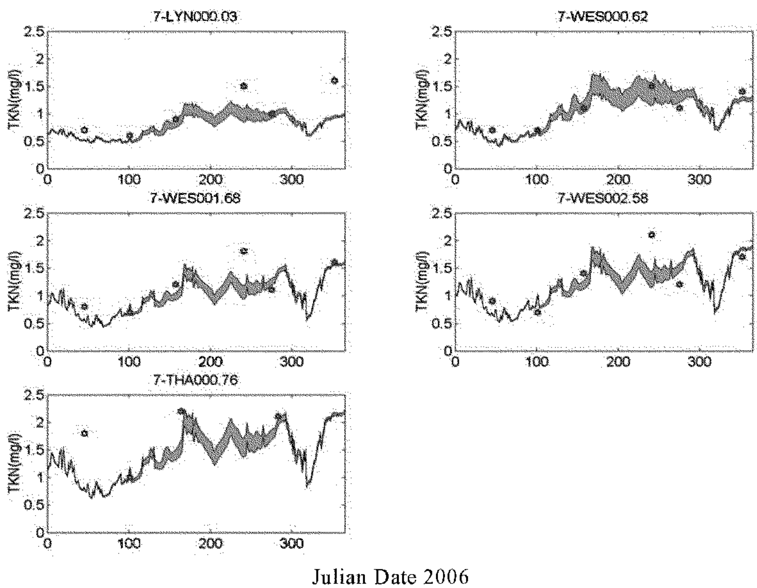


Figure V.21. Predicted vs. observed TKN at Western Branch DEQ stations for 2006.

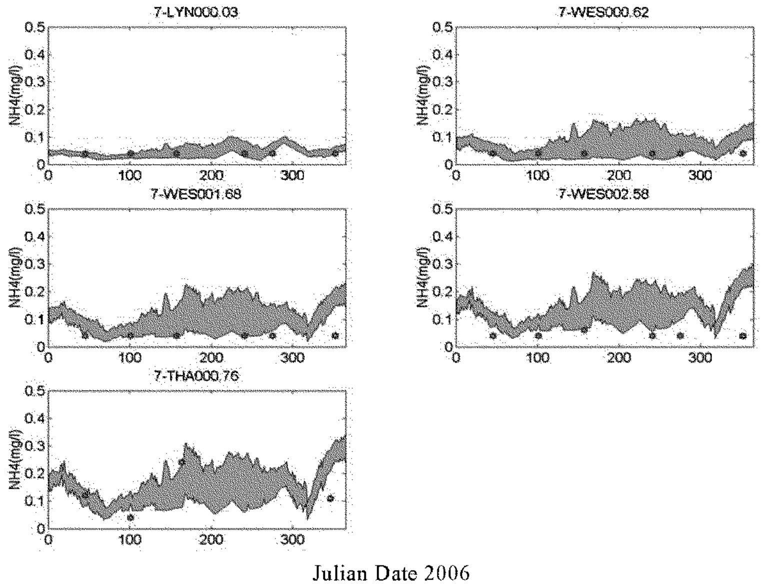


Figure V.22. Predicted vs. observed ammonium at Western Branch DEQ stations for 2006.

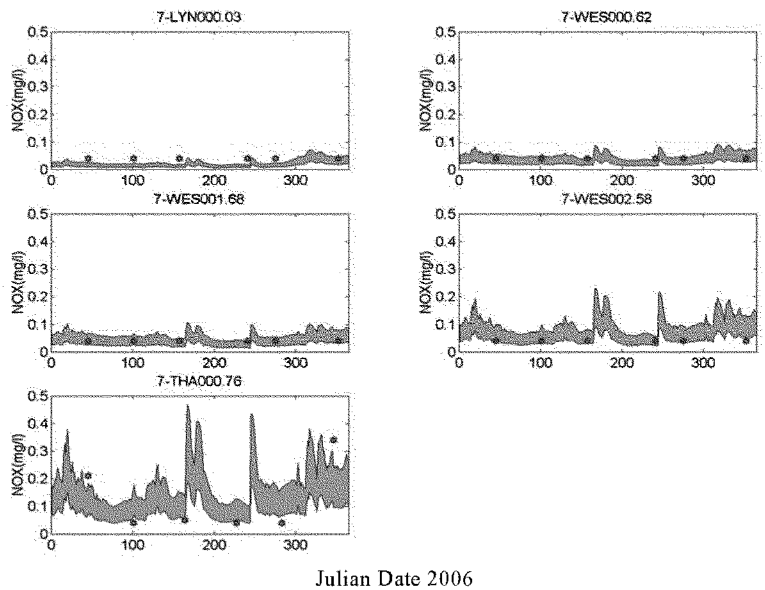


Figure V.23. Predicted vs. observed nitrate-nitrite at Western Branch DEQ stations for 2006.

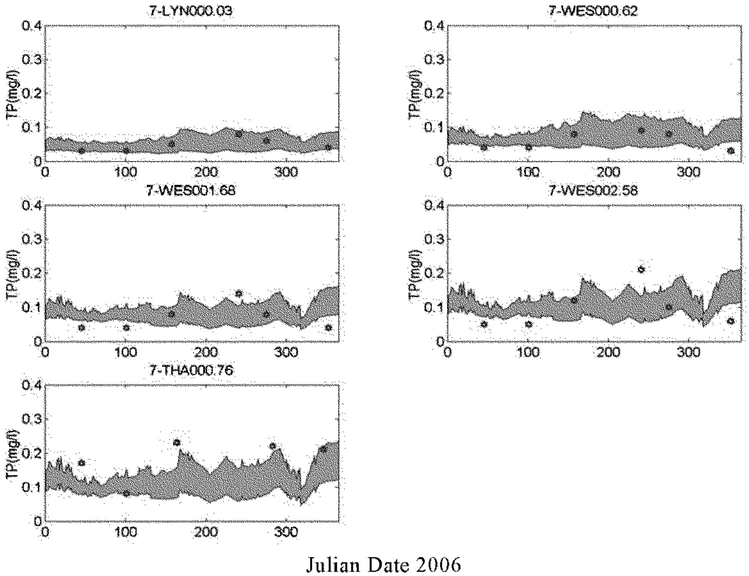


Figure V.24. Predicted vs. observed total phosphorus at Western Branch DEQ stations for 2006.

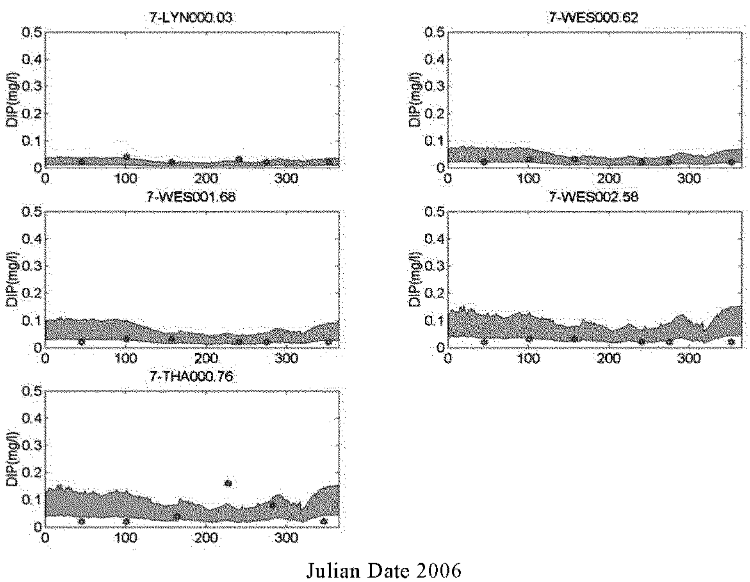


Figure V.25. Predicted vs. observed ortho phosphorus at Western Branch DEQ stations for 2006.

B. Eastern Branch DEQ stations calibration results

The calibration process was continued from the DEQ stations located in the Western Branch to the 6 DEQ stations located in the Eastern Branch. Initially, it was uncertain whether the model calibration coefficients and parameters would be the same in the Eastern Branch as in the Western Branch due to different characteristics. For example, the Eastern Branch is much longer than the Western Branch and includes a canal that was dredged and deepened to the headwater. Since nonpoint sources are the only source of pollutants, the increase in freshwater runoff to the Eastern Branch will have an accompanying increase in pollutant loads that will affect general property of algae growth rates, respiration rates, cell nutrient composition, and sediment characteristics.

At a meeting in June 2005 between representatives of the City of Virginia Beach, the Army Corps, URS, and VIMS, representatives from the City of Virginia Beach expressed a concern that the VIMS modeling domain did not extend to the West Neck Creek region. This region is at the head of the Eastern Branch and is known as the West Neck Creek - London Bridge Creek System, including the Canal No. 2. It was noted that many water quality issues were associated with conditions originating in this system. VIMS thus extended the model domain beyond London Bridge to include West Neck Creek.

After a series of runs comparing between model results and observed data, it became apparent that the new boundary upstream of West Neck Creek produced better results. Given the proper hydrodynamic results, without much change on the water quality parameters, the water quality model results were satisfactory. Water quality model calibration results for Eastern Branch DEQ stations for 2006 are shown in Figures V.26 through V.32. In all figures comparing modeled and measured water quality parameters, the model predictions are represented as a gray band bounded by daily minimum and maximum predictions.

Results for dissolved oxygen are shown in Figure V.26. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen reasonably well, with only a slight over-prediction at the upstream London Bridge (7-LOB001.79) and Canal No. 2 (7-XBO001.30) stations, where summertime DO measurements fall below 5 mg/l. Figure V.27 presents the predicted versus observed comparisons for chlorophyll-a, catching the trend for all stations, but there were a couple of outliers in the sparse observation data. Figure V.28 shows that the model captures the trend of measured TKN values well for all Eastern Branch DEQ stations. The predictions of ammonium and nitrate-nitrite shown in Figures V.29 and V.30, respectively, have some large diurnal fluctuations, but observed values primarily fall within these ranges. Figure V.31 shows that total phosphorus predictions match observations well overall, although these may slightly under-predict in summer at the mid-branch stations of 7-EBL002.54, 5BWNC010.02, and 7-XBO01.30. Ortho phosphorus measurements are captured reasonably well at all stations, as shown in Figure V.32. An inspection of Figures V.26 through V.32 shows gradual increases of both chlorophyll-a and nutrients in moving from the Inlet upstream to West Neck Creek (5BWNC010.02), and a slight decrease in dissolved oxygen is seen moving upstream in the Eastern Branch.

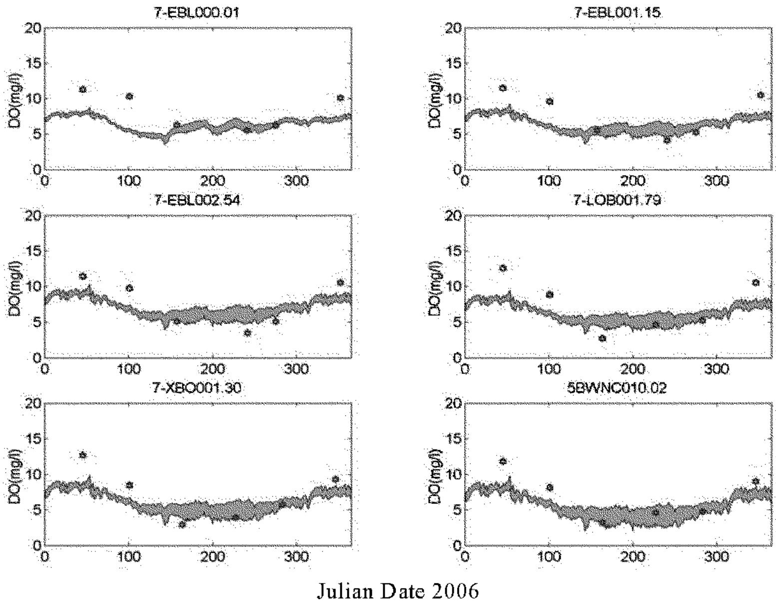


Figure V.26. Predicted vs. observed dissolved oxygen at Eastern Branch DEQ stations for 2006.

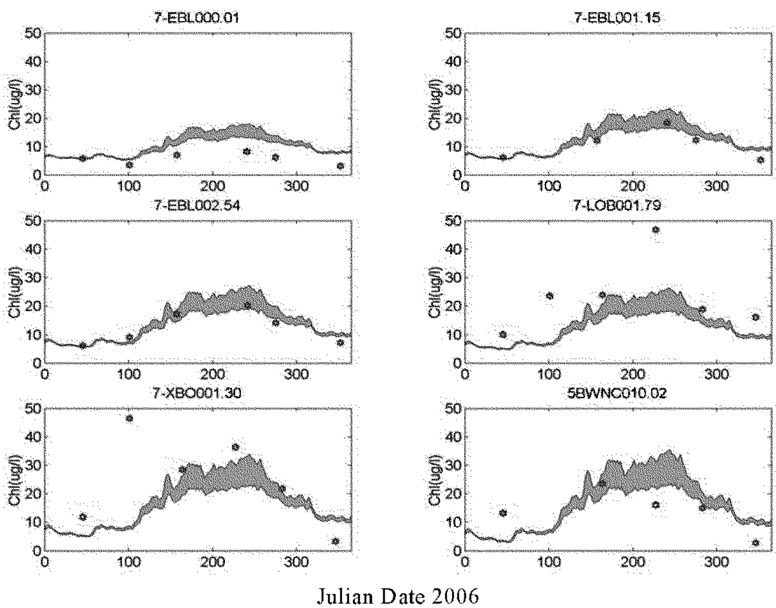


Figure V.27. Predicted vs. observed chlorophyll-a at Eastern Branch DEQ stations for 2006.

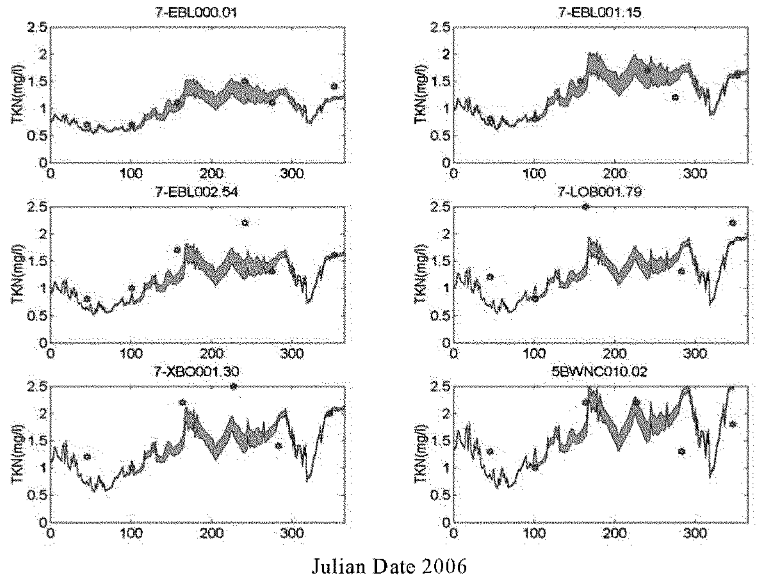


Figure V.28. Predicted vs. observed TKN at Eastern Branch DEQ stations for 2006.

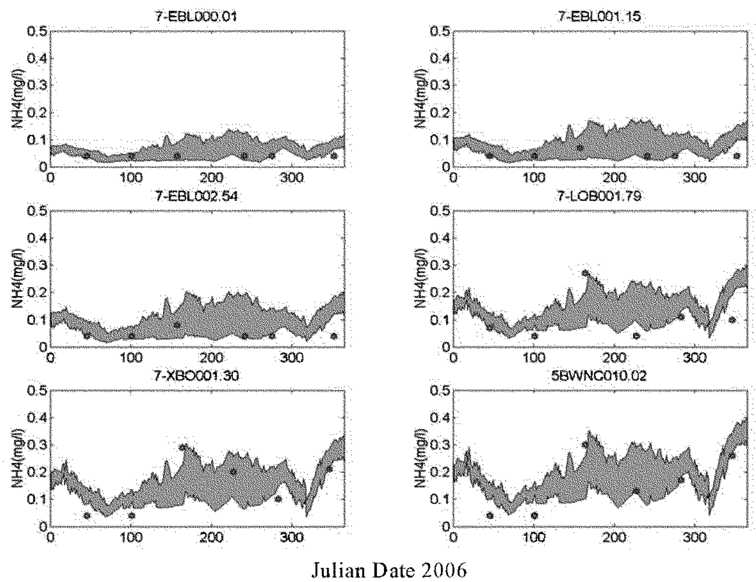


Figure V.29. Predicted vs. observed ammonium at Eastern Branch DEQ stations for 2006.

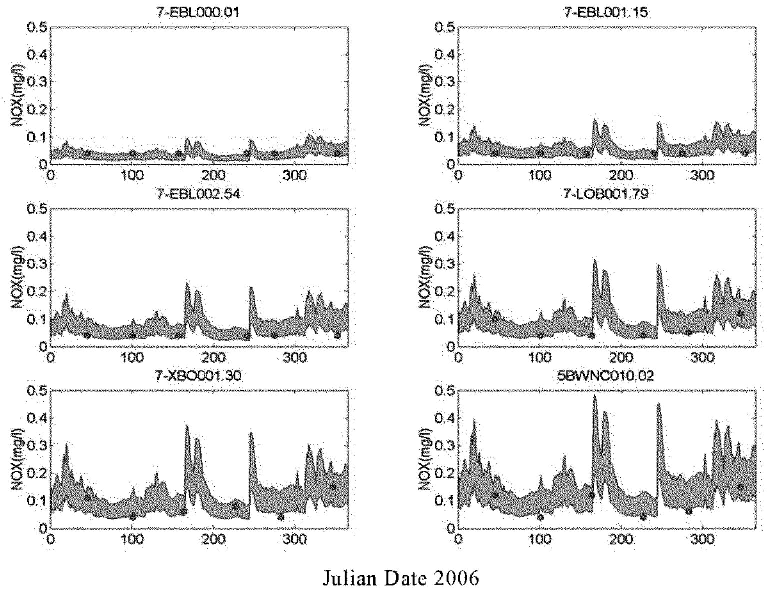


Figure V.30. Predicted vs. observed nitrate-nitrite at Eastern Branch DEQ stations for 2006.

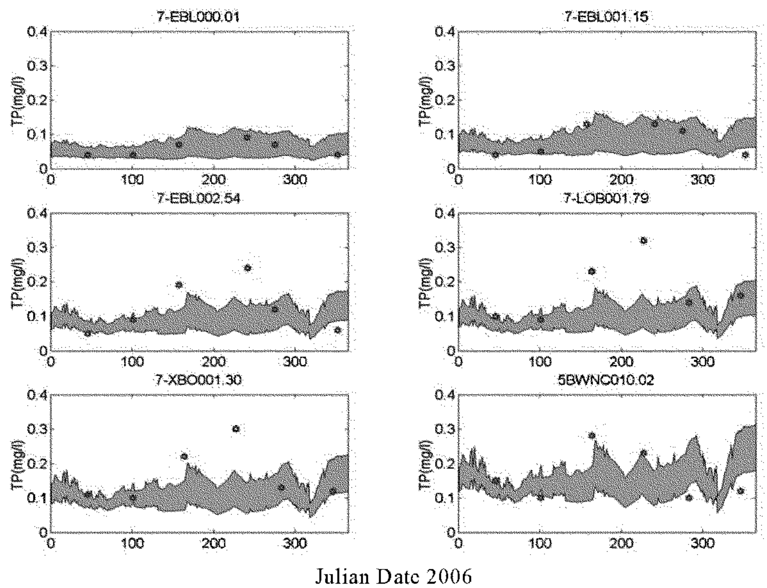


Figure V.31. Predicted vs. observed total phosphorus at Eastern Branch DEQ stations for 2006.

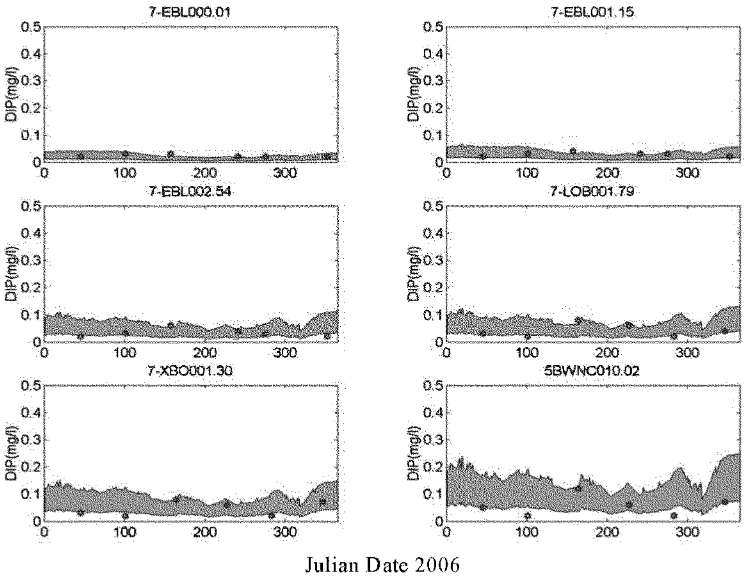


Figure V.32. Predicted vs. observed ortho phosphorus at Eastern Branch DEQ stations for 2006.

C. Broad Bay / Linkhorn Bay Branch DEQ stations calibration results

Water quality model calibration results for Broad Bay /Linkhorn Bay Branch DEQ stations for 2006 are shown in Figures V.33 through V.39. In all figures comparing modeled and measured water quality parameters, the model predictions are represented as a gray band bounded by daily minimum and maximum predictions.

Results for the comparison of modeled versus measured dissolved oxygen at Broad and Linkhorn Bay Branch DEQ stations are shown in Figure V.33. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen extremely well at all 5 DEQ stations in this branch. One may note that all modeled and observed values exceed 5 mg/l throughout the year. Figure V.34 shows reasonably good agreement overall between predicted and observed values for chlorophyll-a, but there may be some over-prediction at upstream stations 7-CRY000.59, 7-LNC000.68, and 7-LKN002.77 beyond Julian Day 280. Figure V.35 shows good agreement between modeled and measured TKN values at all Broad Bay and Linkhorn Bay DEQ stations. The predicted values of ammonium and nitrate-nitrite shown in Figures V.36 and V.37, respectively, match observed values quite well. Figures V.38 and V.39 show that total phosphorus and ortho phosphorus predictions match observations well at all 5 DEQ stations in this branch. An inspection of Figures V.33 through V.39 shows better water quality in this branch than in the Western and Eastern Branches. Finally, there is almost no spatial decrease in dissolved oxygen nor increase in either chlorophyll-a or nutrients in moving from the Inlet upstream to the head of Linkhorn Bay.

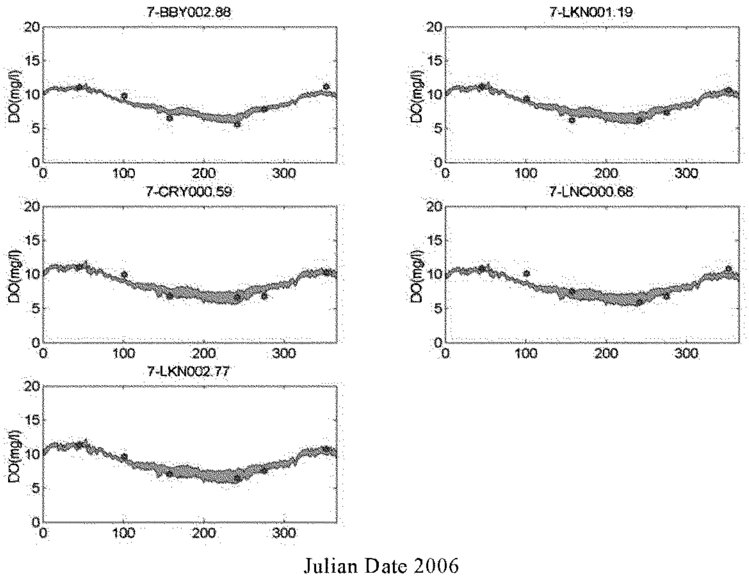


Figure V.33. Predicted vs. observed dissolved oxygen at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

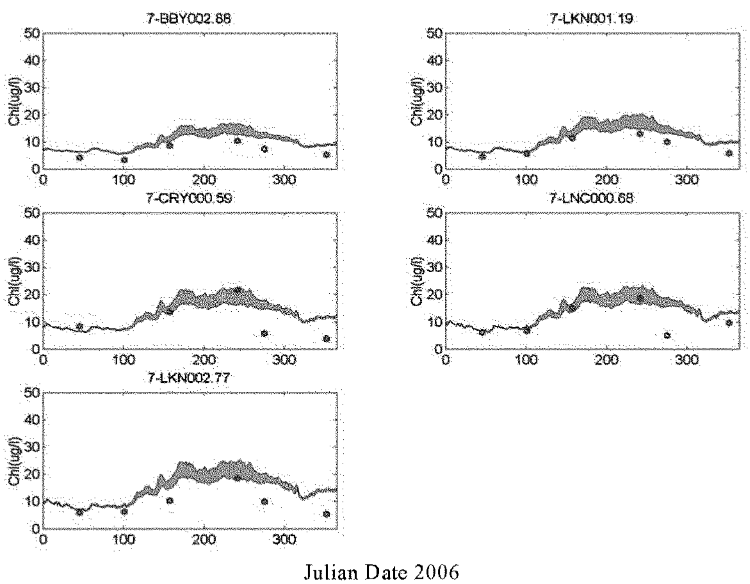


Figure V.34. Predicted vs. observed chlorophyll-a at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

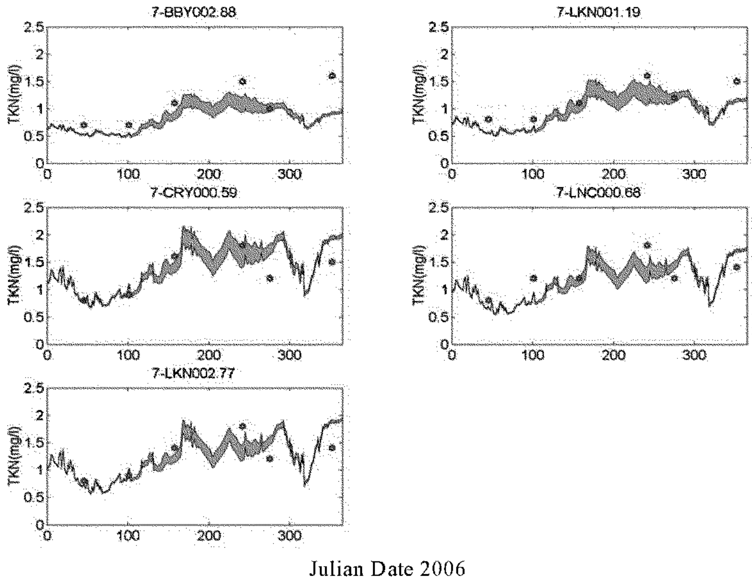


Figure V.35. Predicted vs. observed TKN at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

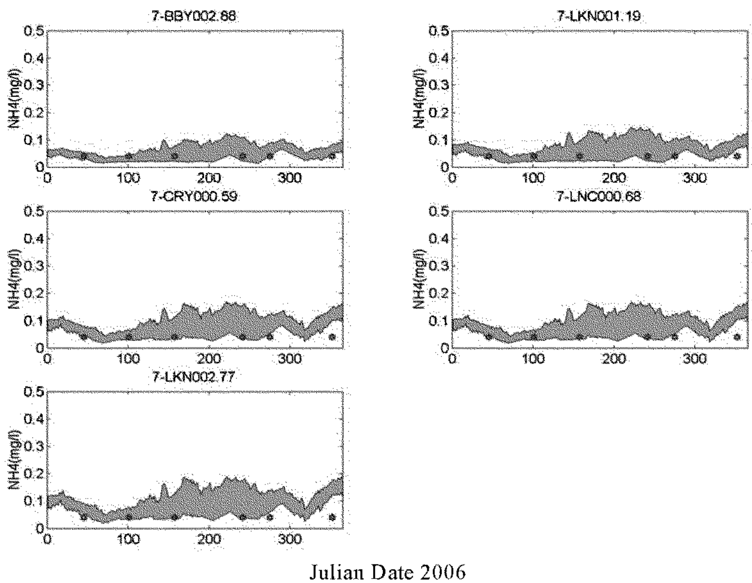


Figure V.36. Predicted vs. observed ammonium at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

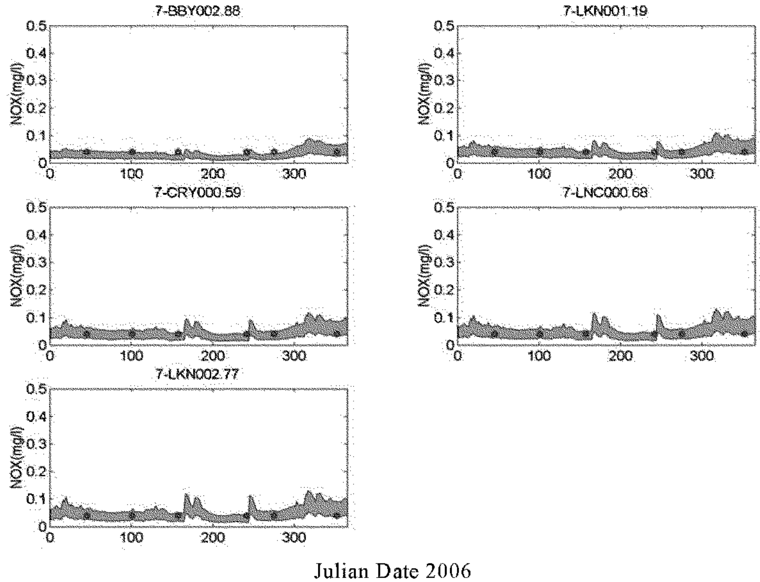


Figure V.37. Predicted vs. observed nitrate-nitrite at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

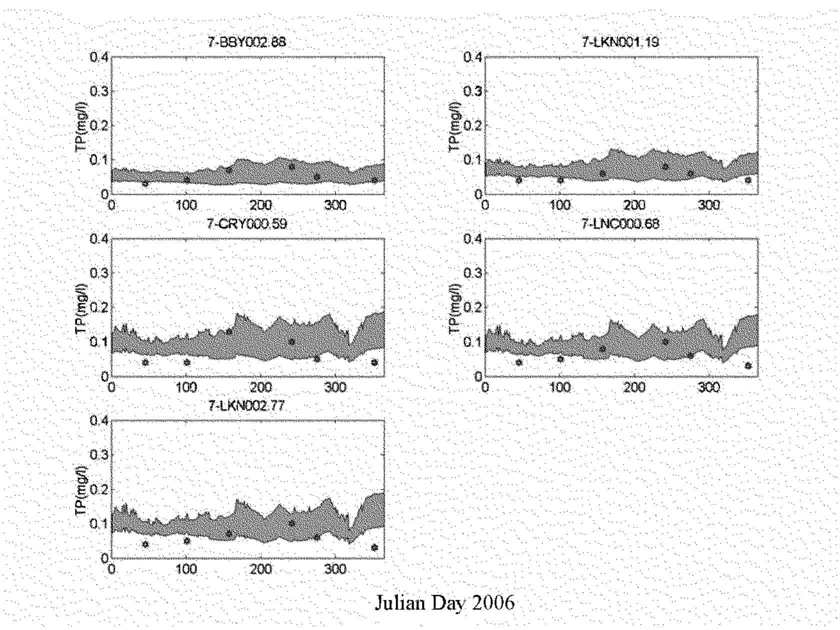


Figure V.38. Predicted vs. observed total phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

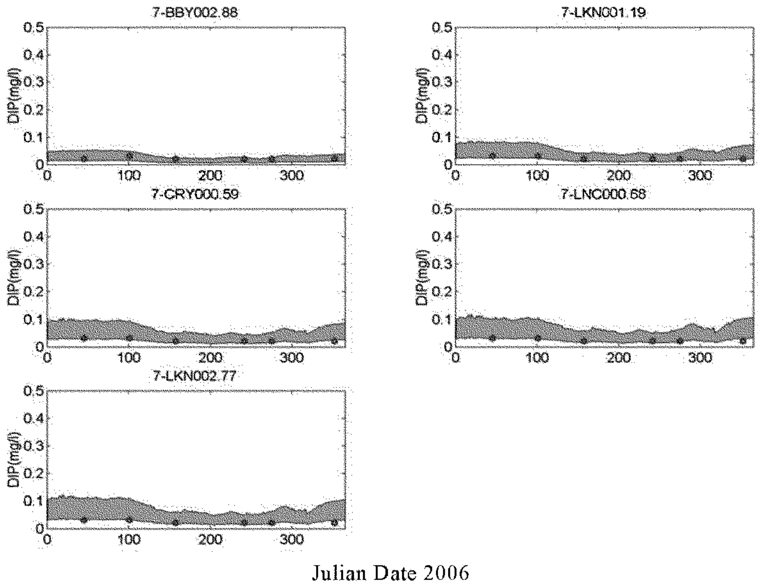


Figure V.39. Predicted vs. observed ortho phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

Summary Statistics of Water Quality Model Calibration Results

In the previous portion of this section, qualitative comparisons between model results and observed values were presented. Although the comparisons indicate that the CE-QUAL-ICM water quality model can reproduce the physical, chemical, and biological processes that affect the eutrophication process in the Lynnhaven River, a more specific measure of the model performance is desirable.

In order to provide a more quantifiable measure of the performance of the water quality model, a statistical analysis was applied to the predicted and observed data of the water quality calibration results.

For model predictions vs. observations of the water quality parameters compared at the surface layer for the year 2006, various error measurements serve to quantify the performance of the water quality model. Error measurements determined include:

1) **Mean error** – The mean error statistic is defined as:

$$ME = \frac{\sum(O-P)}{n}$$

where: ME = mean error, O = observation, P = model predicted result, and n = number of observations. The mean error is a summary of the model tendency to overestimate or underestimate the data.

2) **Absolute Mean error** –The absolute mean error statistic is defined as:

$$AME = \frac{\sum|O-P|}{n}$$

where: AME = absolute mean error. The absolute mean error is a measure of the average discrepancy between observations and model results.

3) **Root-Mean-Square Error** – The root-mean-square error statistic is defined as:

$$RME = \sqrt{\frac{\sum(O-P)^2}{n}}$$

where: RME = root-mean-square error. The root-mean-square error is an alternate quantification of the average discrepancy between observations and model results.

4) **Relative Error** – The relative error statistic is defined as:

$$RE = \frac{\sum|O-P|}{\sum O}$$

where: RE = relative error. The relative error statistic normalizes absolute mean error by the magnitude of the observations.

Additionally, 1:1 plots of predicted results vs. observations show visually how well the model predictions compare with observations and whether the model shows a bias towards either over-prediction or under-prediction.

A. Statistical Analysis of Dissolved Oxygen, Chlorophyll-a, TKN, and Total Phosphorus Results

Statistical analysis of 7 key water quality parameters was performed by comparing predicted and observed results of each parameter for all of the 16 Lynnhaven DEQ stations combined. The every-other-month DEQ measurements taken during the 2006 year thus provided sample sizes of 90, 86, 90, and 90, respectively, for DO, chl-a, TKN, and TP predicted vs. observed comparisons at all Lynnhaven River DEQ stations. The 1:1 plots are shown in Figure V.40 for these 4 comparisons and their corresponding error measures are shown in Table V.12. Overall, predicted and observed DO values compare well. The median value for mean error is about 0.69 mg/l while the absolute mean error is 1.07 mg/l. The root-mean-square error for both surface and bottom DO is about 1.47

mg/l, whereas the relative error is around 13%. These statistics are comparable to other eutrophication model studies such as the Three-dimensional Eutrophication Model Study of the Chesapeake Bay (Cerco and Cole, 1994).

It was also worthwhile to point out that the absolute mean error and root-mean-square error of water quality parameters shown in Table V.12 are well within the range of natural variation in a given season of measurements when compared with available observations, for example, Figures V.19-V.21, V.24, V.26-V.28, V.31, V.33-V.35, and V.38.

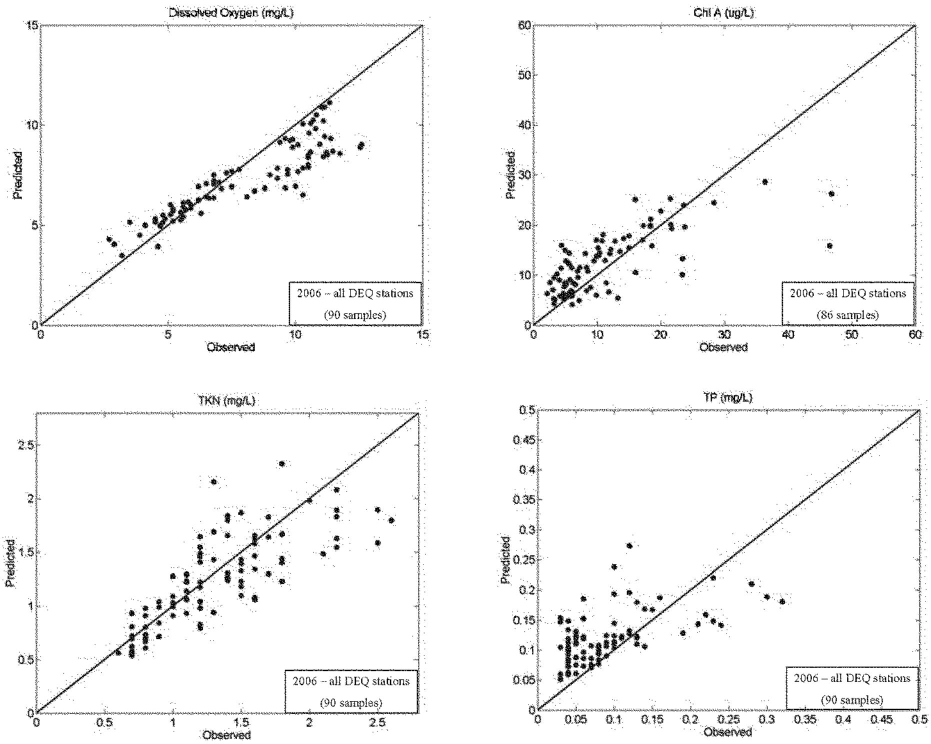


Figure V.40. Plots of 1:1 predicted vs. observed DO, chl-a, TKN, and TP at all 16 Lynnhaven DEQ stations for 2006.

Table V.12. Statistical summary of errors derived by comparing predicted vs. observed surface values of DO, chl-a, TKN, and TP for year 2006.

Surface Comparisons of Predicted vs. Observed Dissolved Oxygen, Chlorophyll-a, TKN, and Total Phosphorus				
	All 16 Lynnhaven DEQ Stations			
	DO	Chl-a	TKN	TP
Sample size	90	86	90	90
Mean Error	0.69	-0.67	0.08	-0.03
Absolute Mean Error	1.07	4.82	0.23	0.05
RMS Error	1.47	8.06	0.31	0.06
Relative Error	0.13	0.40	0.18	0.52
Corr. Coeff. (r)	0.90	0.66	0.79	0.60

B. Statistical Analysis of Ammonia, Nitrate-Nitrite, and Dissolved Inorganic Phosphate

To quantify the comparison between predicted and observed values NH_4, NO_x, and DIP, determination of statistical errors and construction of 1:1 plots were performed for these parameters as well. Table V.13 below shows error values of each parameter for predicted vs. observed comparisons of all 16 Lynnhaven DEQ stations combined for 2006.

The nitrogen and phosphorus are major nutrients that can be used for photosynthesis. In particular, NH_4, NO_x, and dissolved phosphorus are species that can be uptaken directly by the phytoplankton. Therefore, they are important indicators for the environmental quality. Nitrogen's concentration is usually higher than that of phosphorus. The 1:1 plots of predicted vs. observed comparisons of NH_4, NO_x, and DIP are shown in Figure V.41. The summary is shown in Table V.13. The absolute mean error and root-mean-square error of these water quality parameters show the differences between model predictions and observations are within the range of natural variation in a given season of measurements when compared with available observations, for example, as shown in Figures V.22-V.23, V.25, V.29-V.30, V.32, V.36-V.37, and V.39.

Table V.13. Statistical summary of errors derived by comparing predicted vs. observed values of NH_4, NO_X, and DIP for all 16 Lynnhaven DEQ stations for 2006.

Parameter:	NH_4	NO_X	DIP
Sample Size	90	90	90
Mean Error	-0.04	-0.02	-0.02
Absolute Mean Error	0.04	0.03	0.02
RMS Error	0.05	0.04	0.03
Relative Error	0.73	0.57	0.79
Corr. Coeff. (r)	0.74	0.76	0.42

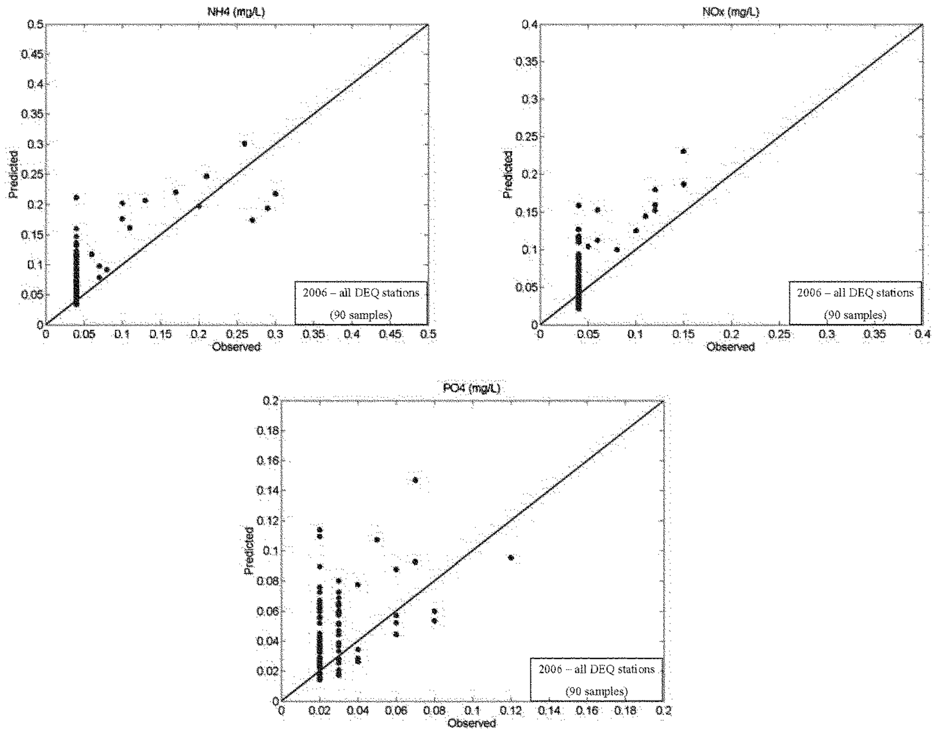


Figure V.41. Plots of 1:1 predicted vs. observed NH_4, NO_x, and DIP.

V-3 Calibration of the Sediment Transport Model

The model was calibrated by adjusting the erosion coefficient M to make the modeled results agree with observation data. The TSS observation data of 2006 collected at the 16 Lynnhaven DEQ stations (locations shown earlier in Figure V.18) were used to calibrate the model. The comparisons between model predictions and observations for TSS are shown in Figures V.42 through V.44, respectively, for the Western, Eastern, and Broad Bay / Linkhorn Bay DEQ stations for calibration year 2006.

Validation of the sediment transport model, using the 2004 and 2005 DEQ data, is shown in Chapter VI, Section VI-3.

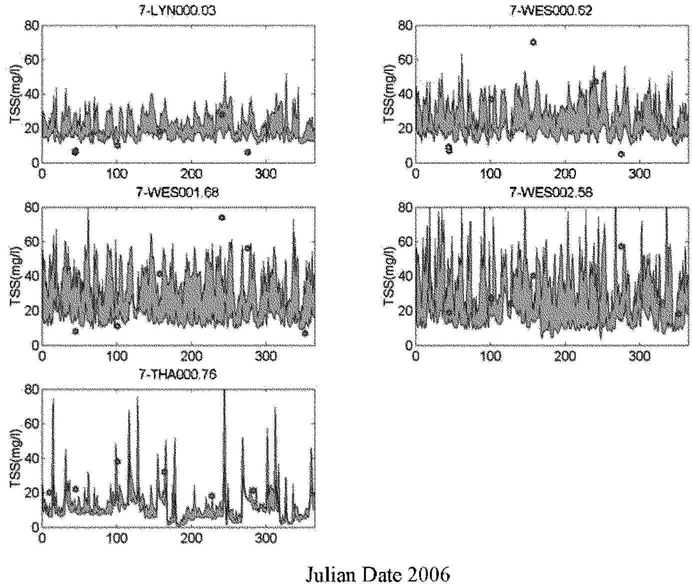


Figure V.42. Predicted vs. observed TSS at Western Branch DEQ stations for 2006.

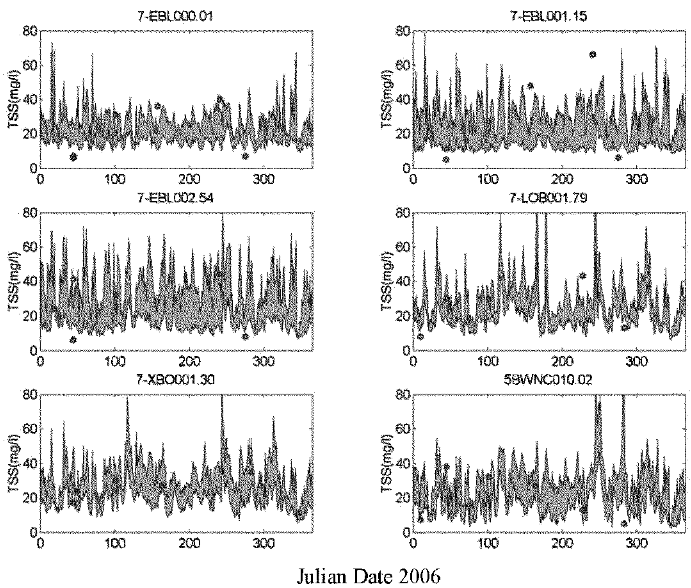


Figure V.43. Predicted vs. observed TSS at Eastern Branch DEQ stations for 2006.

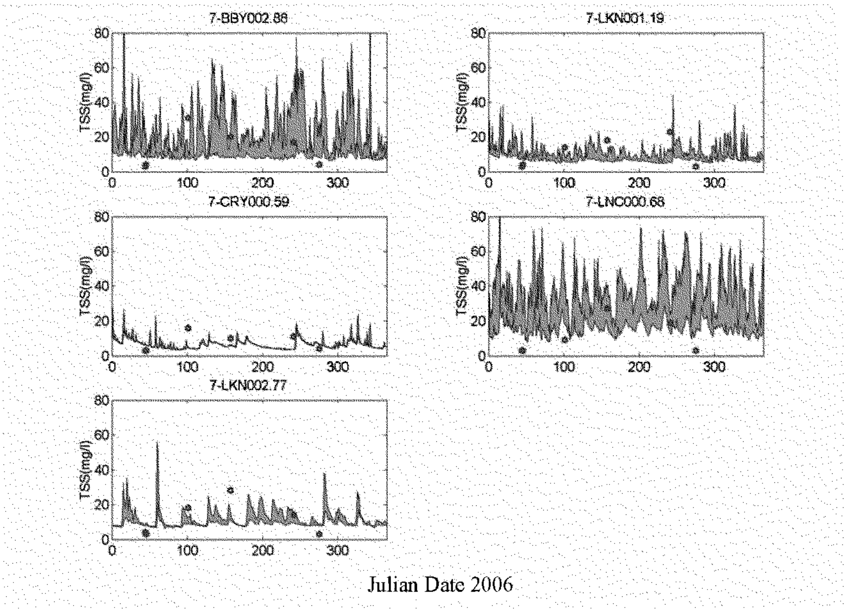


Figure V.44. Predicted vs. observed TSS at Broad Bay / Linkhorn Bay Branch DEQ stations for 2006.

CHAPTER VI. MODEL VALIDATION

The hydrodynamic and water quality models applied to the Lynnhaven River system were developed using the framework outlined in Chapter III. Chapter V describes how the models were calibrated based on 2006 intensive field measured data described. As part of quality control, the model validation is a process for independent checking that the modeling results meet specifications using a different dataset and that it fulfils its intended purpose.

The hydrodynamic model was validated using synoptic data collected in September and November 2005 and the water quality model for the years 2004 and 2005, during which period both the freshwater discharge and the non-point source loading data were provided by the HSPF watershed model in Lynnhaven River, developed by URS Corporation.

VI-1 Validation of the Hydrodynamic Model

It was critical to conduct a systematic, high-frequency hydrodynamic survey, measuring water elevations inside the inlet synoptically with representative currents and salinities in each branch as well as outside of the Inlet (see Section IV-2-A for a full description of the VIMS Lynnhaven hydrodynamic survey). With these data in hand, validation then

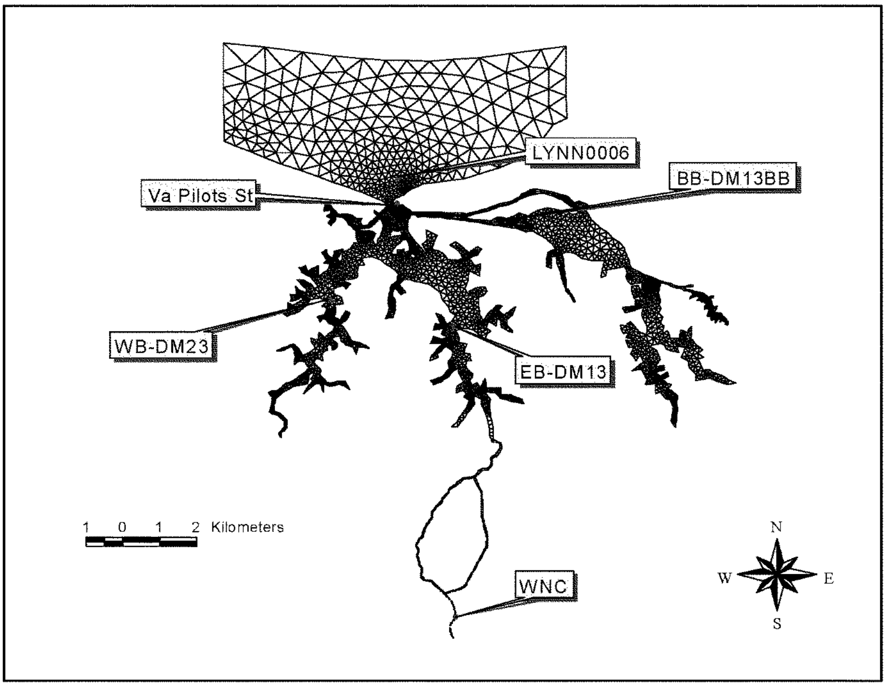


Figure VI.1. Locations of Lynnhaven observation stations (tide and velocity) in 2005.

consisted of a real-time simulation of the prototype condition for periods in September and November, 2005, during which time high-frequency observations of tides, as well as representative high-frequency velocities and salinities in each branch, were available.

VI-1-1 Validation for tidal elevation

In September 2005, a tidal gauge was deployed for 2 weeks in the upper Eastern Branch at West Neck Creek (WNC). In November 2005, a 30-day deployment was made at the Virginia Pilot Station, just inside the Inlet. Locations of these 2 stations are shown in Figure VI.1.

These tidal observations in 2005 were compared to UnTRIM model results from a real-time simulation invoking both the freshwater discharge provided by URS and high frequency wind from the Chesapeake Bay Bridge Tunnel (CBBT) station. The comparison of UnTRIM modeled predictions with observations is shown in Figure VI.2.

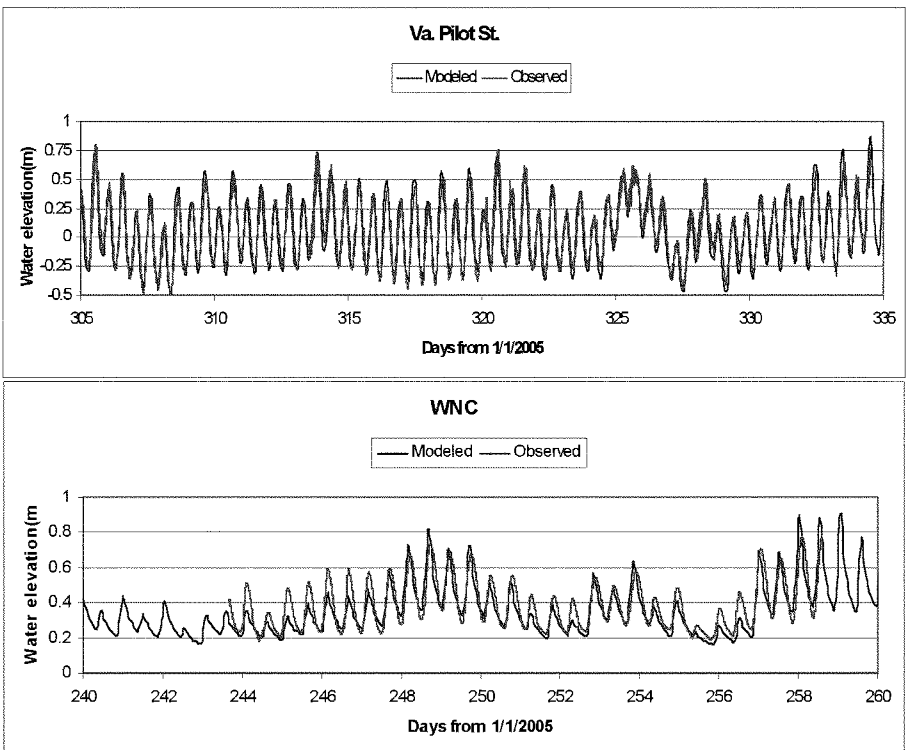


Figure VI.2. Modeled versus observed water elevations at the Virginia Pilot's station (November 2005) and in West Neck Creek (September 2005).

VI-1-2 Validation for velocity

For the VIMS hydrodynamic survey conducted in November 2005, the measurements of tidal velocity were made over a 30-day period using an ADP instrument outside the inlet and an S4 current meter at representative locations of each Lynnhaven branch. Locations of these instruments are shown in Figure VI.3 below.

Figure VI.3. Locations of Lynnhaven Velocity Stations, November 2005.

The bottom-mounted ADP outside the Inlet measured velocities at 10 layers in the vertical at a frequency of every 20 minutes for the 30-day deployment. The S4 instruments deployed in each branch measured mid-depth velocity at 30-minute intervals over the deployment.

East-west and north-south component comparisons between observed and predicted currents outside the Inlet are shown in Figure VI.4. The modeled and observed velocity magnitude and direction comparisons are shown for the Western, Eastern, and Broad Bay branches, respectively, in Figures VI.5 through VI.7. In general, good agreement is shown between modeled and observed tidal velocities.

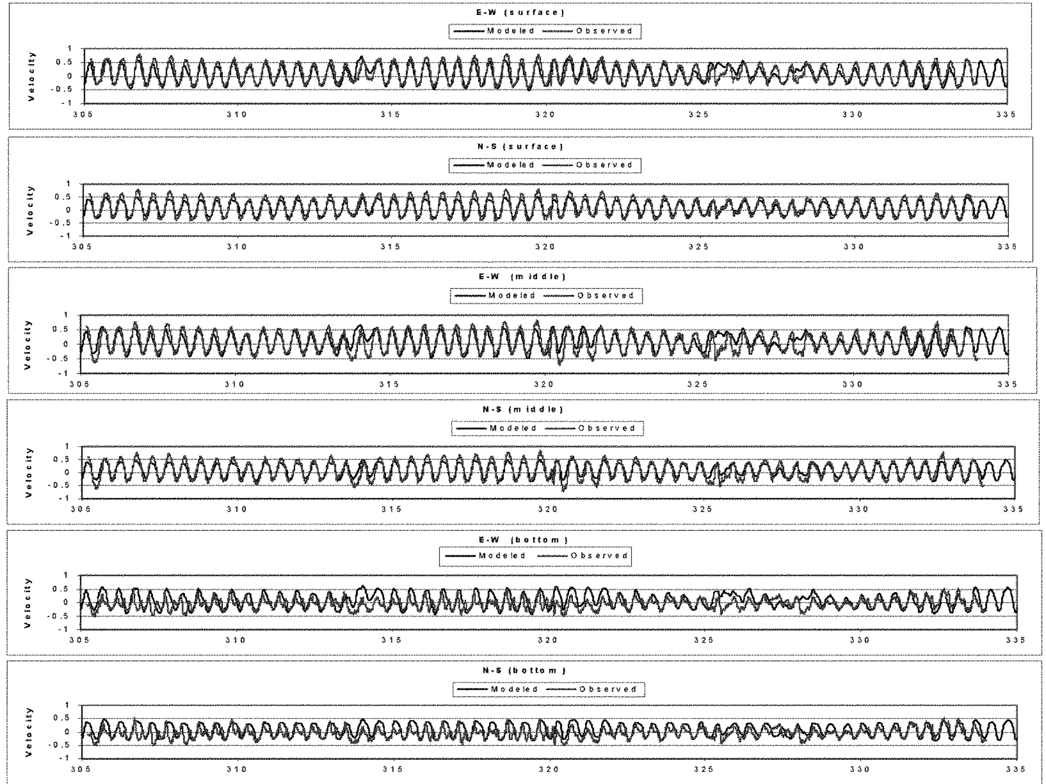
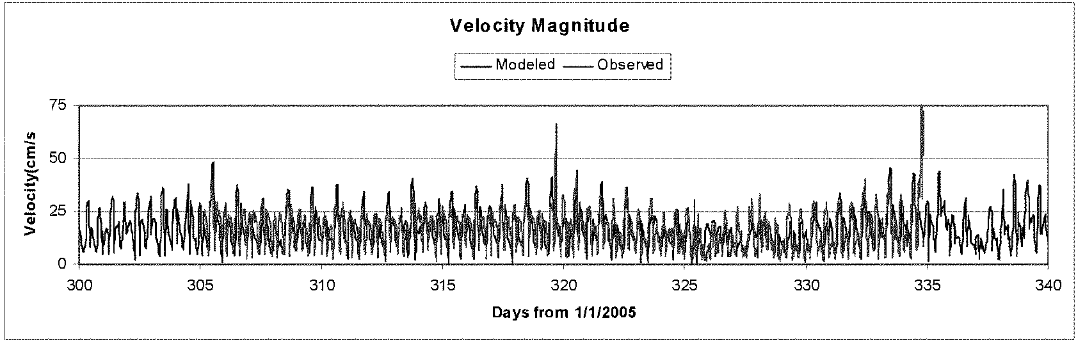


Figure VI.4. East-west and north-south components of measured versus modeled velocity at surface, middle, and bottom layers outside Lynnhaven Inlet.

Comparison of Velocity (Western Branch)



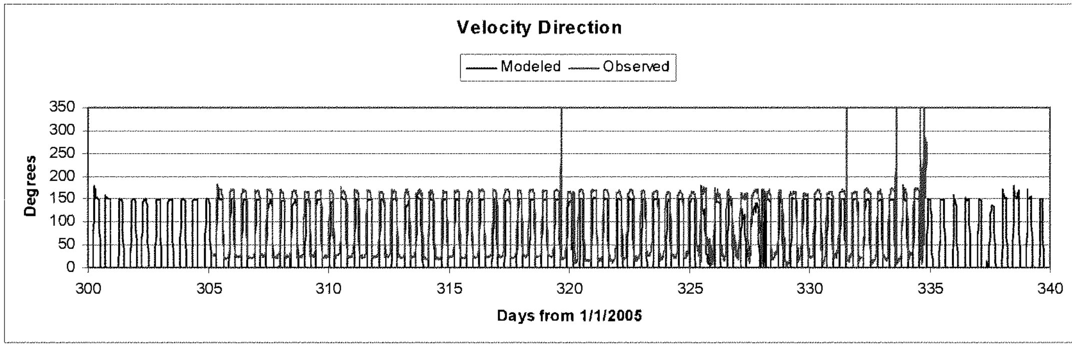


Figure VI.5. Magnitude and direction of measured versus modeled velocity at mid-depth in the Western Branch.

Comparison of Velocity (Eastern Branch)

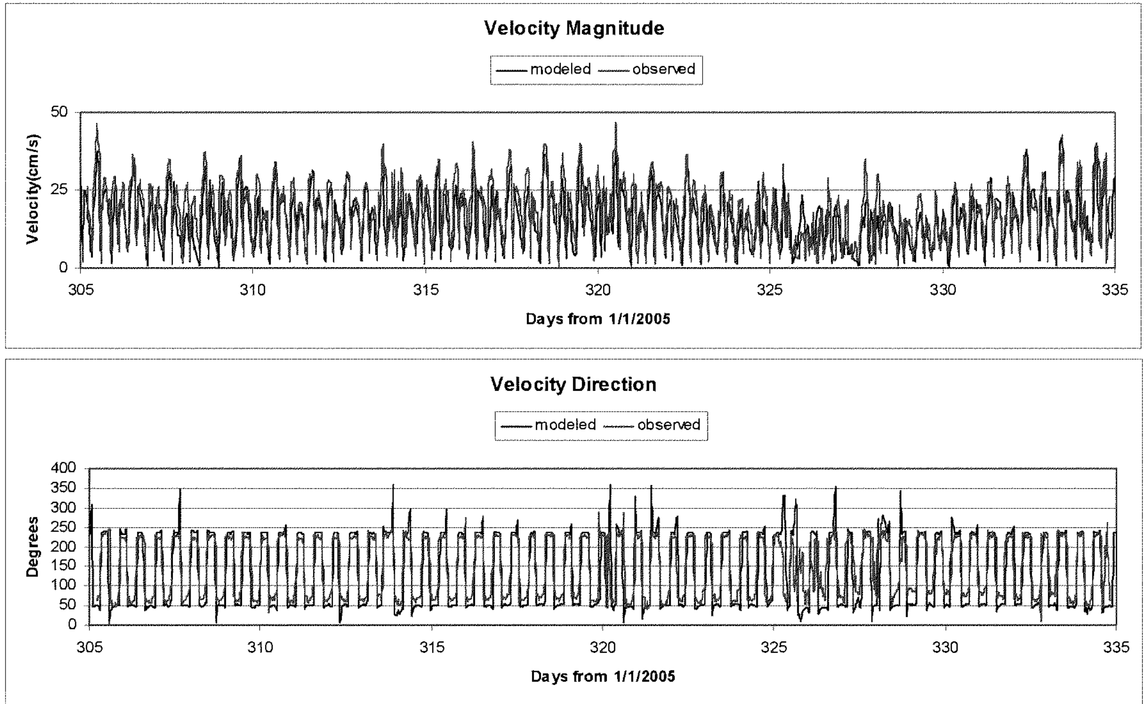


Figure VI.6. Magnitude and direction of measured versus modeled velocity at mid-depth in the Eastern Branch.

Comparison of Velocity (Broad Bay)

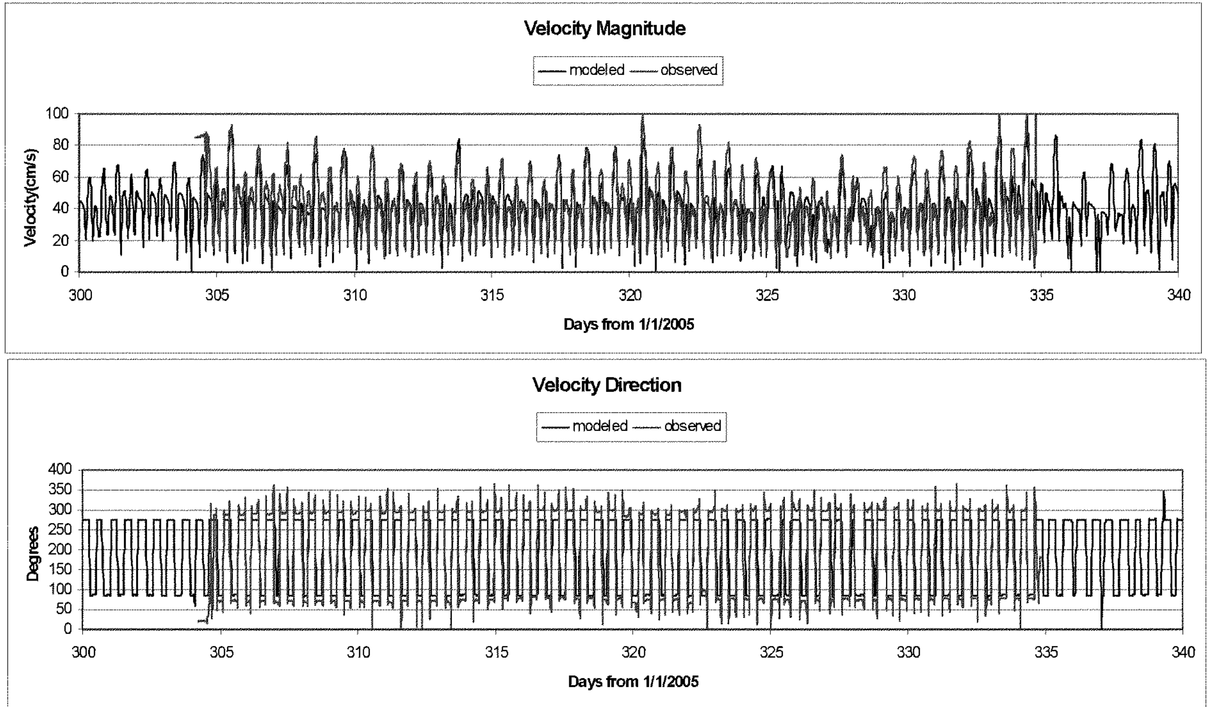


Figure VI.7. Magnitude and direction of measured versus modeled velocity at mid-depth in Broad Bay.

VI-1-3 Validation for salinity

In order to validate salinity predicted by the UnTRIM hydrodynamic model, comparisons between measurements and model predictions were made at all 16 VA-DEQ stations monitored every other month in the Lynnhaven River throughout calendar years 2004 and 2005. Measured data also included those made by the VIMS dataflow surveys during this period (please note that the dataflow coverage did not extend to all 16 stations). The locations of these stations are shown below in Figure VI.8 and the modeled vs. measured salinities for 2004-2005 are shown in Figures VI.9-VI.10, VI.11-VI.12, and VI.13-VI.14, respectively, for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches.

VI-1-4 Validation for temperature

The locations of these stations are shown in Figure VI.8 and the modeled vs. measured temperatures for 2004-2005 are shown in Figures VI.15-VI.16, VI.17-VI.18, and VI.19-VI.20, respectively, for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches.

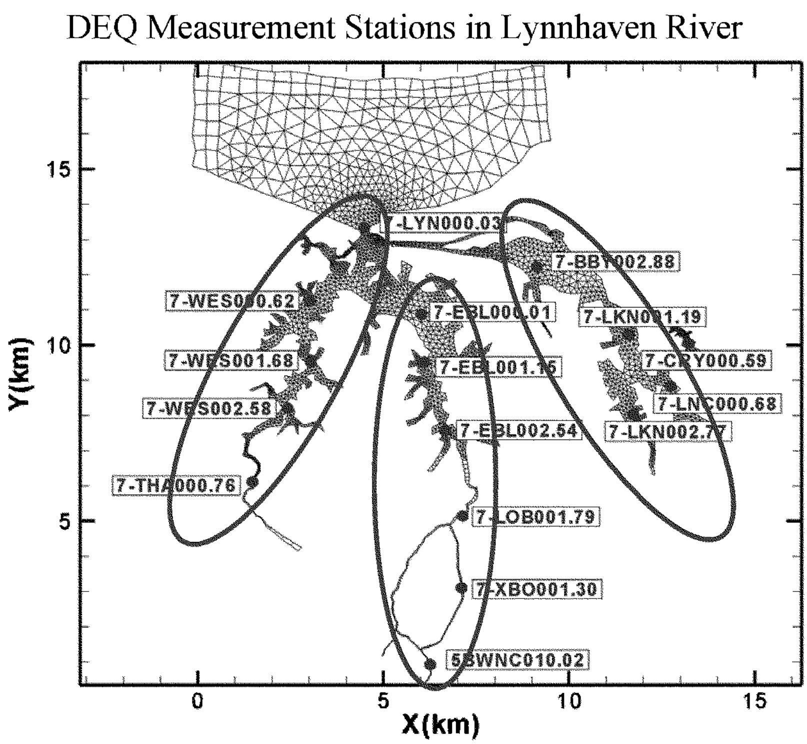
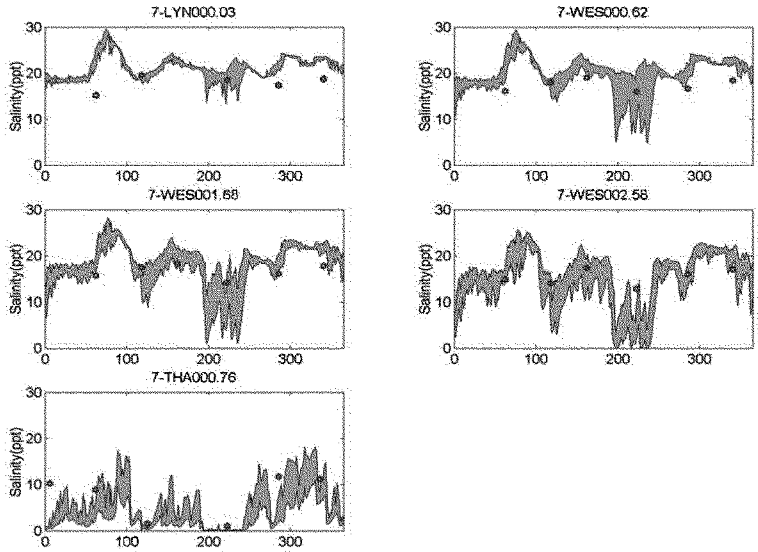
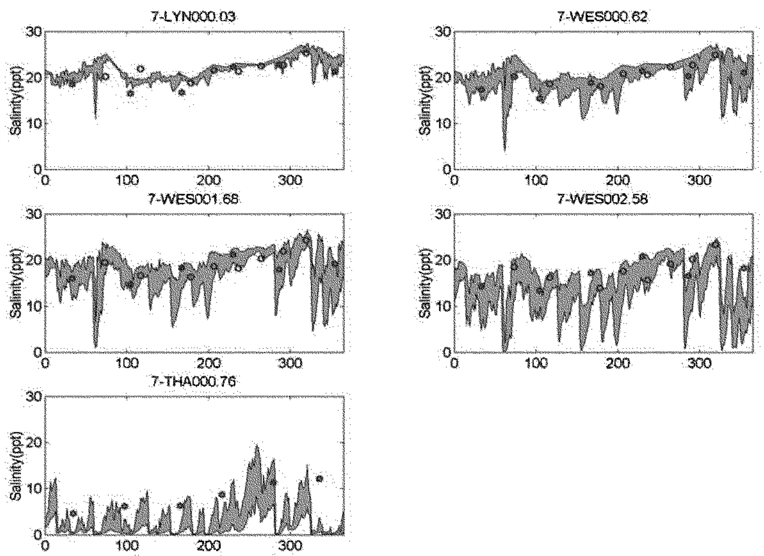


Figure VI.8. Grouping by branch of Lynnhaven DEQ stations as used to compare measured and modeled salinity, temperature, and CE-QUAL-ICM water quality model validation results.



Julian Day 2004

Figure VI.9. UnTRIM modeled versus measured salinities at Western Branch DEQ stations for 2004.



Julian Day 2005

Figure VI.10. UnTRIM modeled versus measured salinities at Western Branch DEQ stations for 2005. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.

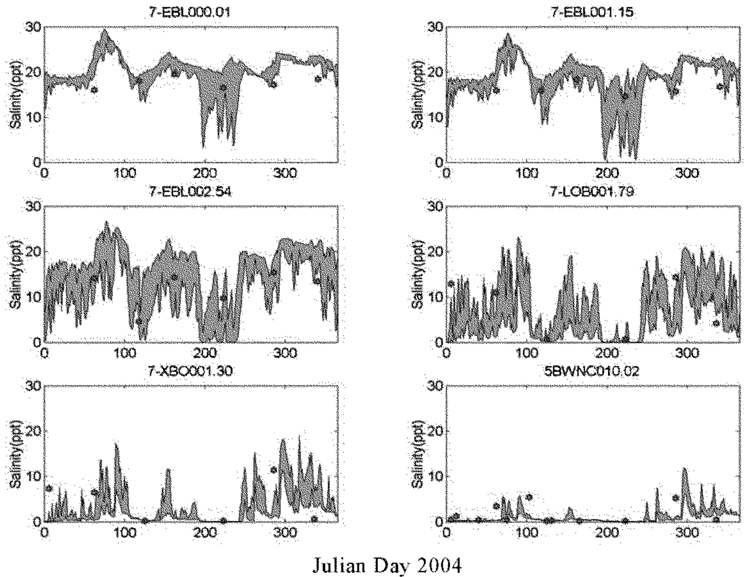


Figure VI.11. UnTRIM modeled versus measured salinities at Eastern Branch DEQ stations for 2004.

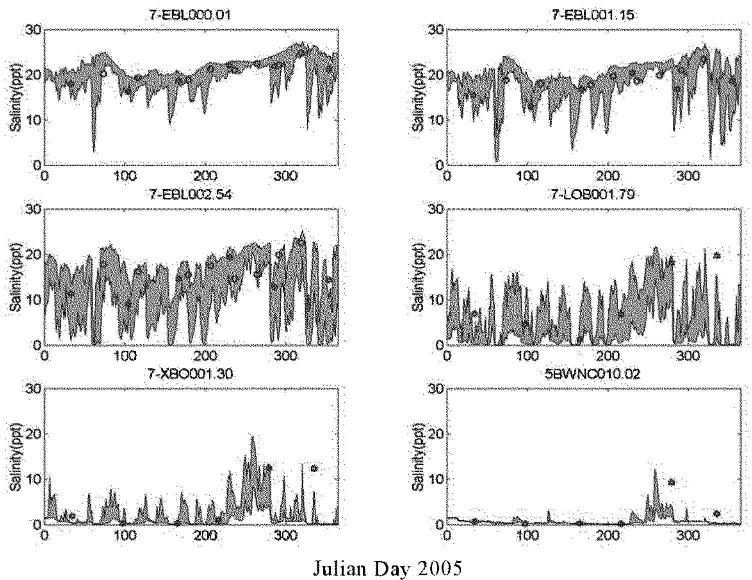
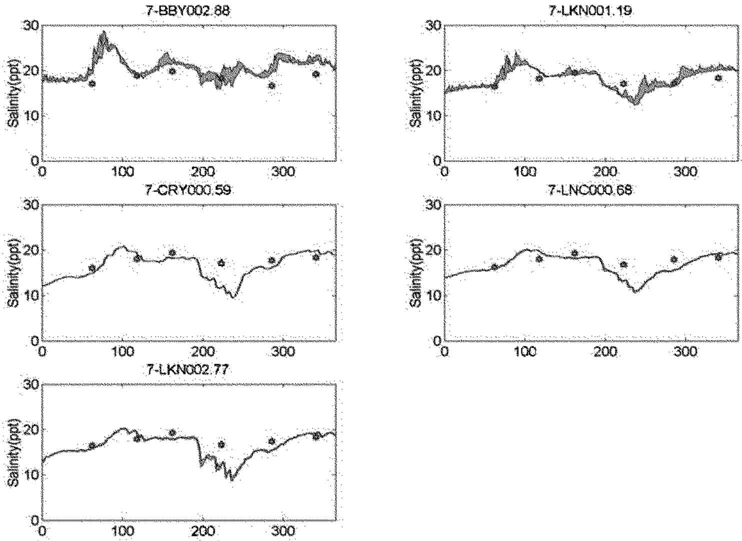
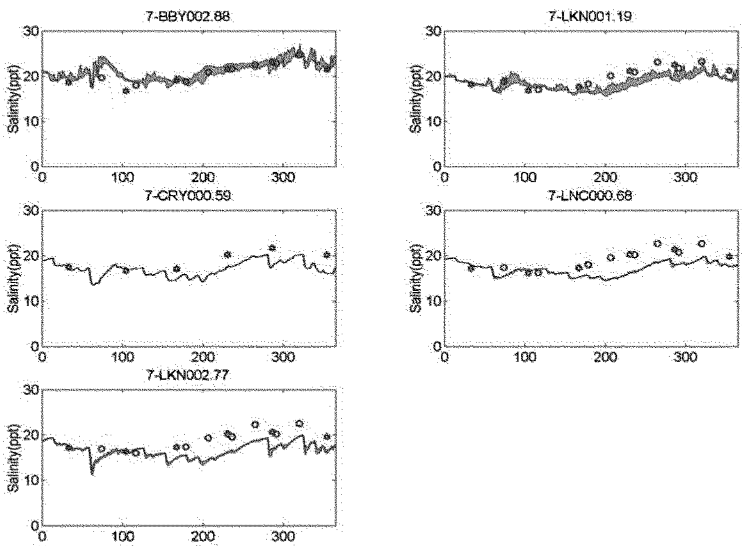


Figure VI.12. UnTRIM modeled versus measured salinities at Eastern Branch DEQ stations for 2005. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.



Julian Day 2004

Figure VI.13. UnTRIM modeled versus measured salinities at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.



Julian Day 2005

Figure VI.14. UnTRIM modeled versus measured salinities at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005. Red asterisks denote DEQ measurements and red circles denote VIMS dataflow measurements.

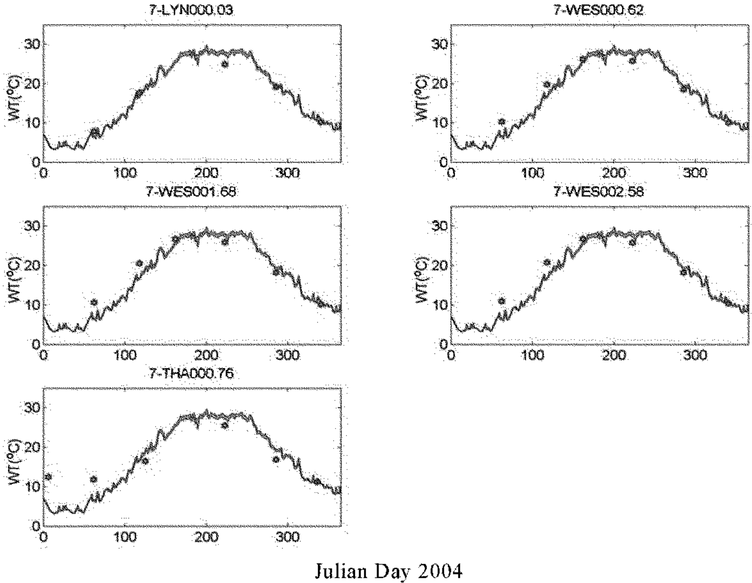


Figure VI.15. UnTRIM modeled versus measured temperatures at Western Branch DEQ stations for 2004.

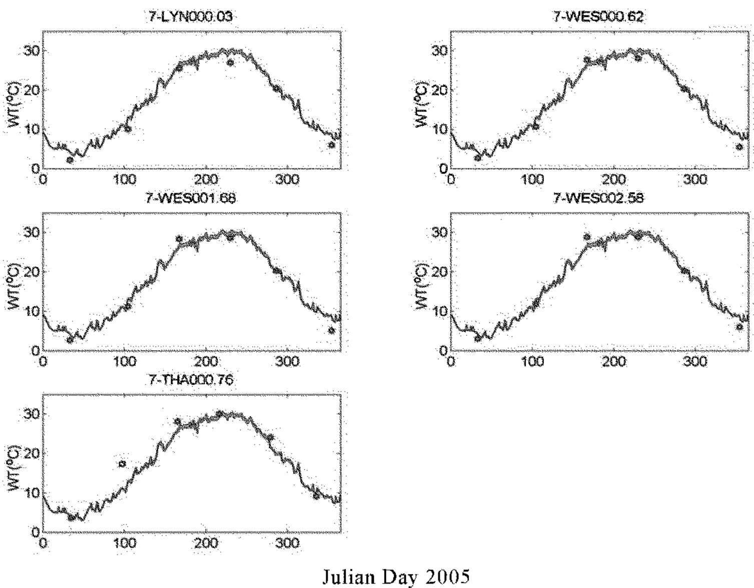


Figure VI.16. UnTRIM modeled versus measured temperatures at Western Branch DEQ stations for 2005.

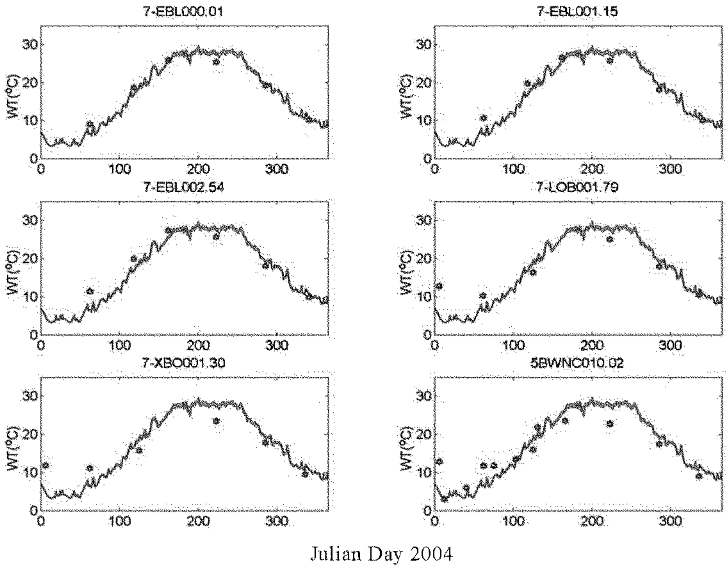


Figure VI.17. UnTRIM modeled versus measured temperatures at Eastern Branch DEQ stations for 2004.

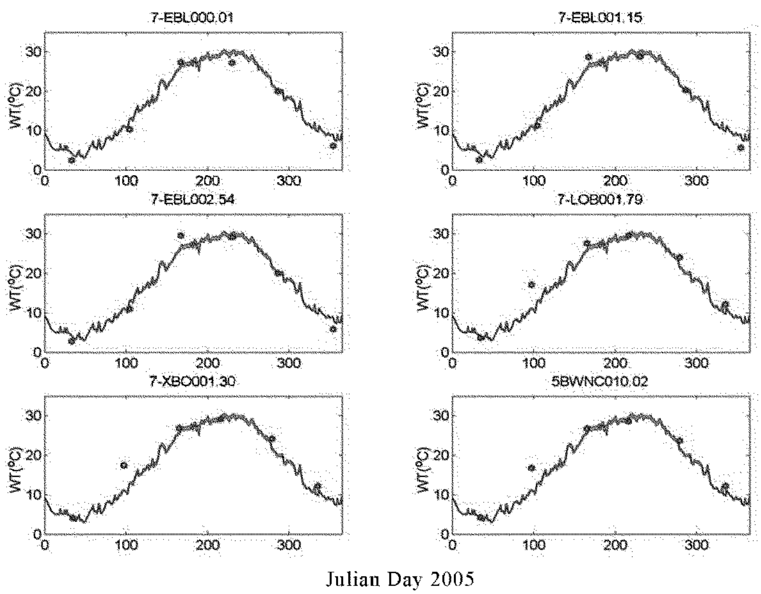


Figure VI.18. UnTRIM modeled versus measured temperatures at Eastern Branch DEQ stations for 2005.

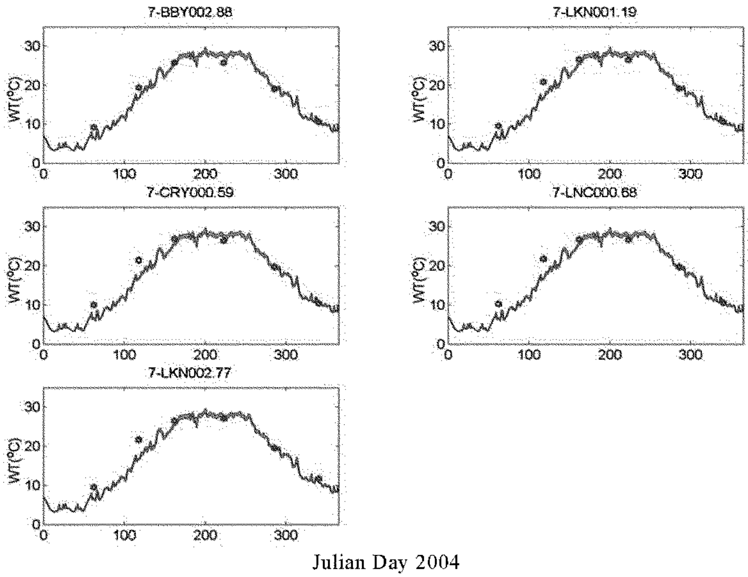


Figure VI.19. UnTRIM modeled versus measured temperatures at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

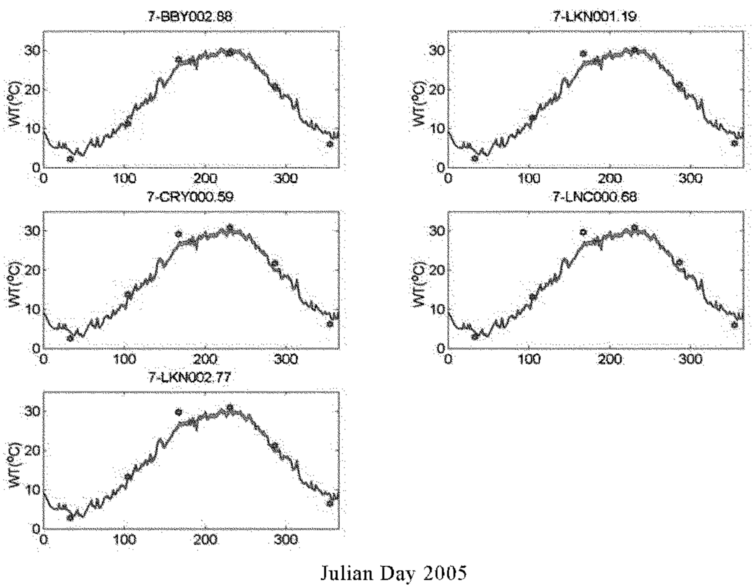


Figure VI.20. UnTRIM modeled versus measured temperatures at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

VI-2 Validation of the Water Quality Model

The overall objective of the model validation procedure is to confirm the predictive capability of the CE-QUAL-ICM model by simulating an entirely different period than that selected for model calibration. Results of the calibration simulation (2006) are shown in Chapter V, Section V-2-5.

Because some parameters were not measured by DEQ in 2004 and in the first half of 2005 due to Virginia State budgetary restrictions that impacted the DEQ monitoring program, the full period of 2004-2005 was selected for model validation.

VI-2-1 Model Validation Results

Lynnhaven hydrologies in 2004 and 2005 differ from that in 2006. On an annual basis, the year of 2004 had higher freshwater input than 2005 and 2005, in turn, had higher input than 2006. In other words, the year 2006 had the lowest freshwater input among 2004, 2005, and 2006. As a result, the salinity of 2006 was the largest and that of 2004 was the smallest. This is part of a long-term trend of decreasing freshwater water input spanning from 2003 to 2008 noted from James River freshwater records.

On the seasonal basis, the year 2004 has a relatively dry winter/spring (from day 70 – 100) but a wet summer (from day 180- 210). On the contrary, the year 2005 had a wet winter/spring (from day 50- 75) and a dry summer/fall (from day 210 – 270). This pattern shift affects the seasonal variation of the water quality within the yearly cycle.

In terms of the annual temperature pattern, the year 2005 had the highest summer water temperature reaching 29.8 degrees Celsius in August, followed by 2006 and 2004. It does not, however, show a significant seasonal shift over the three years 2004-2006. Water quality variables are affected by both salinity and temperature and, thus, it is important to recognize that there are inter-annual, as well as seasonal, variations.

Given that the physical parameters varied from year to year, it is obvious that there will be ramifications on the water quality variables both in terms of their loading as well as the result of chemical kinetics. Validation of the water quality model took place by comparison of time series plots of selected water quality parameters with DEQ observations at the 16 locations shown earlier in Figure VI.8. As was done for the display of calibration results, stations of each Lynnhaven River branch are clustered in the figures comparing observed versus predicted values of each parameter for stations of that branch to facilitate the comparison.

Model simulation results at each station are shown for the full calendar years of 2004 and 2005 and include the primary water quality parameters of dissolved oxygen, chlorophyll-a, TKN, ammonia, nitrate-nitrite, total phosphorus, and ortho phosphorus. Due to the restrictions on monitoring in 2004 and early 2005, validation comparisons of TKN, ammonium, nitrate-nitrite, and ortho phosphorus are limited to the latter half of 2005.

A. Western Branch DEQ stations validation results

As described above, the hydrological conditions in 2004 and 2005 are quite different from those in 2006. After the calibration has been performed for the year of 2006, the validation provides an independent check of whether the modeling results can meet specifications using different hydrological datasets and fulfils its intended purpose.

Keep in mind, however, that between 2004 and 2005, the seasonal patterns are also different. The year of 2004 has a dry spring and wet summer whereas the year of 2005 has a wet spring, but a dry summer. Water quality model validation results for Western Branch DEQ stations for 2004 and 2005 are carried out with different salinity patterns and the reaction constants that are temperature-dependent. The results are shown in Figures VI.21 through VI.34. In all figures, the model predictions are represented as a gray band bounded by daily minimum and maximum.

Results for dissolved oxygen in 2004 and 2005, respectively, are shown in Figures VI.21 and VI.22. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen quite well. The seasonally low DO values (i.e., below 5 mg/l) measured throughout the Western Branch around Julian Day 200 of 2005 were well-captured by model predictions. Figures VI.23 and VI.24 present the predicted versus observed comparisons for chlorophyll-a, catching the trend for the downstream stations, but showing some isolated discrepancies at the upstream stations 7-WES002.58 and 7-THA000.76. Figures VI.25 and VI.26 show model predictions of TKN during 2004 and 2005 for all Western Branch DEQ stations. Observed TKN was only available in latter 2005, but showed good agreement with predictions over this period. The predictions of ammonium shown in Figures VI.27 and VI.28 for 2004 and 2005, respectively, have similar seasonal trends at all stations, and the available observed data from the latter part of 2005 match the predictions reasonably well at all Western Branch DEQ stations. Figures VI.29 and VI.30 show predictions of nitrate-nitrite for 2004 and 2005, respectively, and the available observation measurements of the latter part of 2005 are shown to match reasonably well. An inspection of Figures VI.31 through VI.34 shows that both total phosphorus and ortho-phosphorus measurements are captured reasonably well at all Western Branch DEQ stations.

As in the case of comparisons of observed vs. predicted parameter values for the model calibration (2006) shown in Chapter V, an inspection of Figures VI.21 through VI.34 shows the gradual decrease of dissolved oxygen and increases of both chlorophyll-a and nutrient levels in moving from the Inlet upstream to Thalia Creek. This is a spatial gradient pattern that is consistent with what was observed in the historical data. The shift on the spring and summer pattern basically reflects the difference of the hydrological year. The model does respond truthfully to the real environmental conditions.

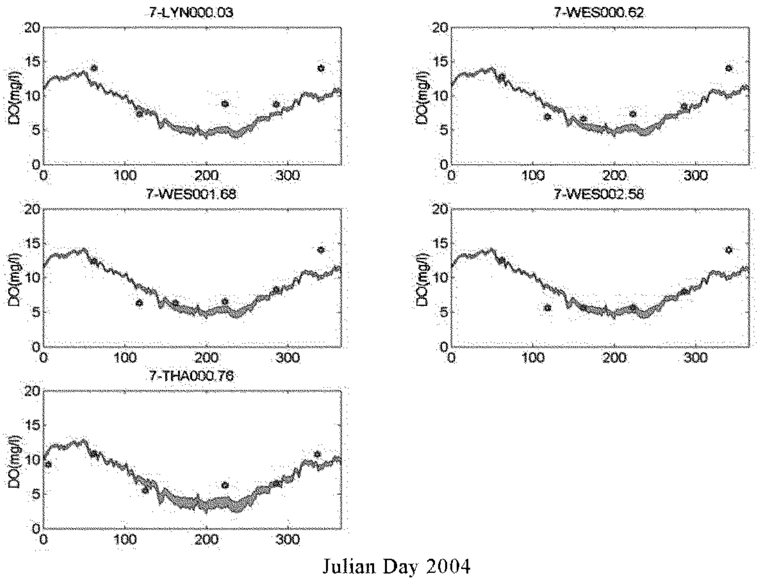


Figure VI.21. Predicted vs. observed dissolved oxygen at Western Branch DEQ stations for 2004.

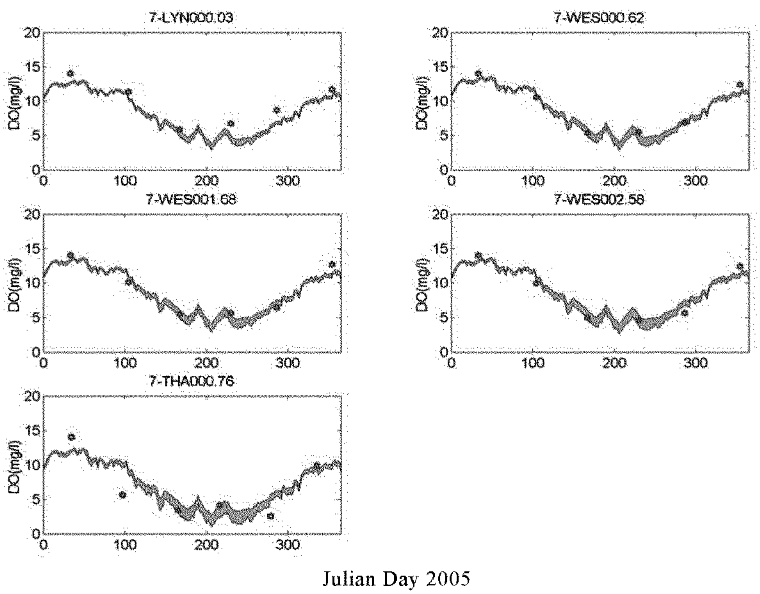


Figure VI.22. Predicted vs. observed dissolved oxygen at Western Branch DEQ stations for 2005.

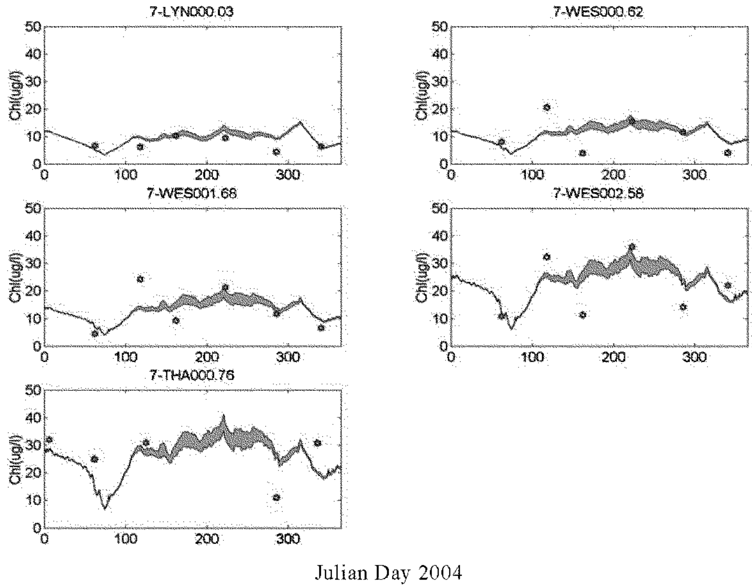


Figure VI.23. Predicted vs. observed chlorophyll-a at Western Branch DEQ stations for 2004.

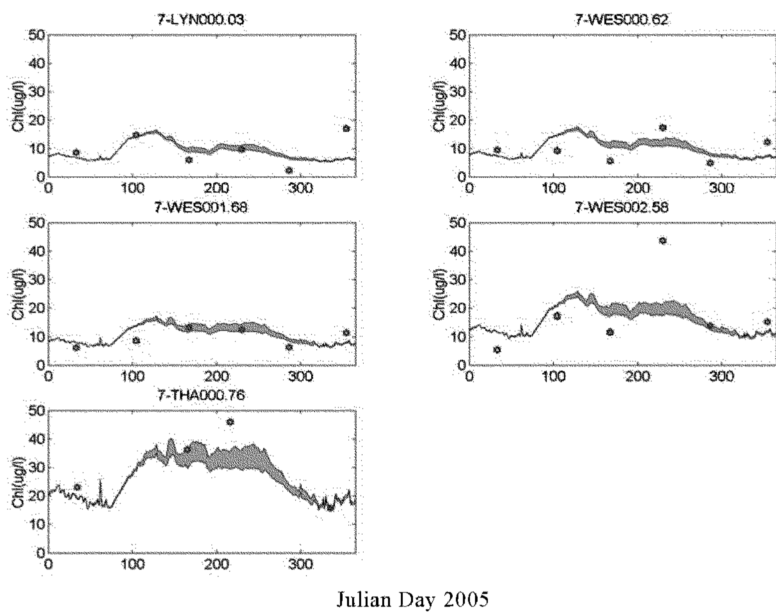


Figure VI.24. Predicted vs. observed chlorophyll-a at Western Branch DEQ stations for 2005.

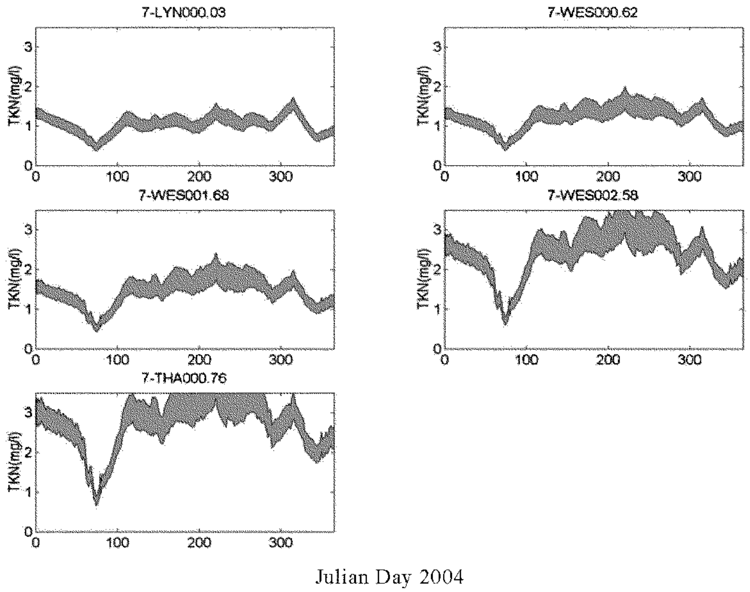


Figure VI.25. Predicted TKN at Western Branch DEQ stations for 2004.

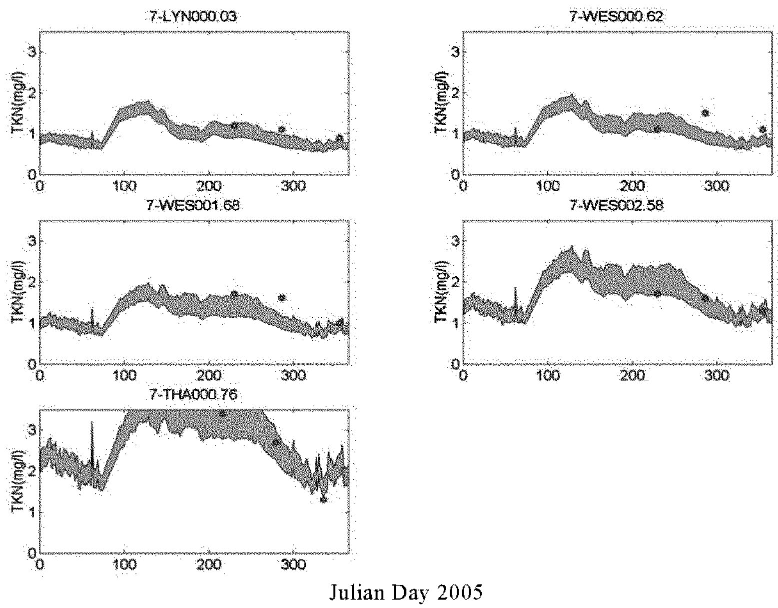


Figure VI.26. Predicted vs. observed TKN at Western Branch DEQ stations for 2005.

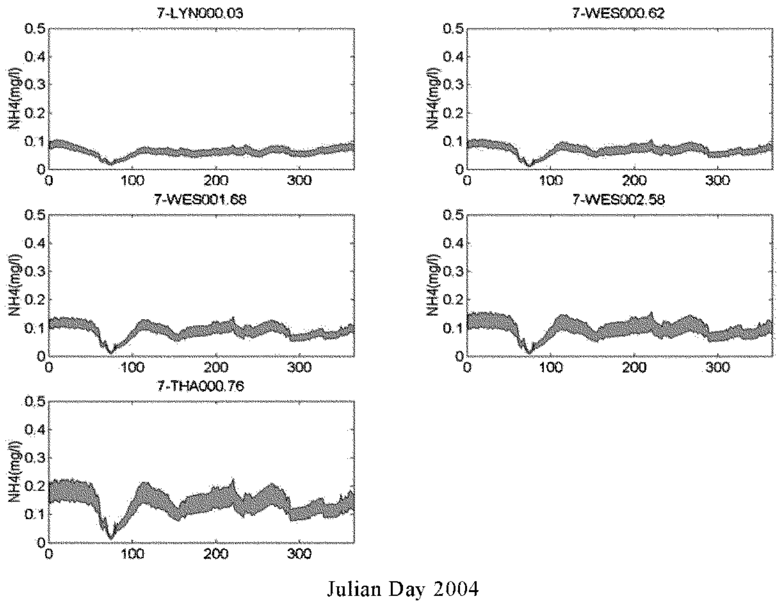


Figure VI.27. Predicted ammonium at Western Branch DEQ stations for 2004.

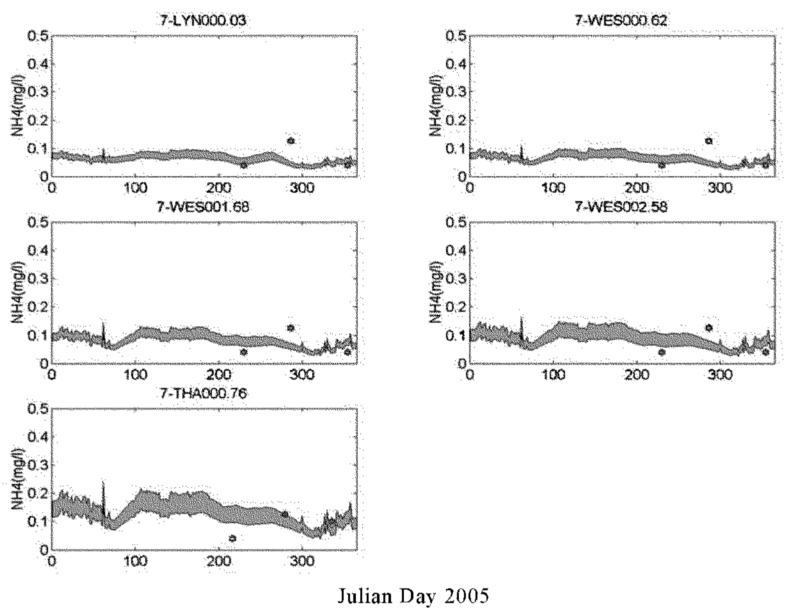


Figure VI.28. Predicted vs. observed ammonium at Western Branch DEQ stations for 2005.

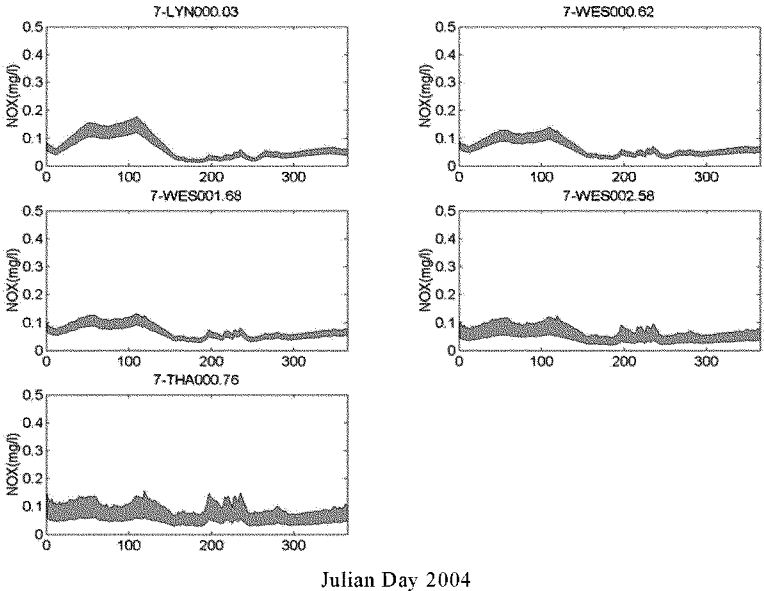


Figure VI.29. Predicted nitrate-nitrite at Western Branch DEQ stations for 2004.

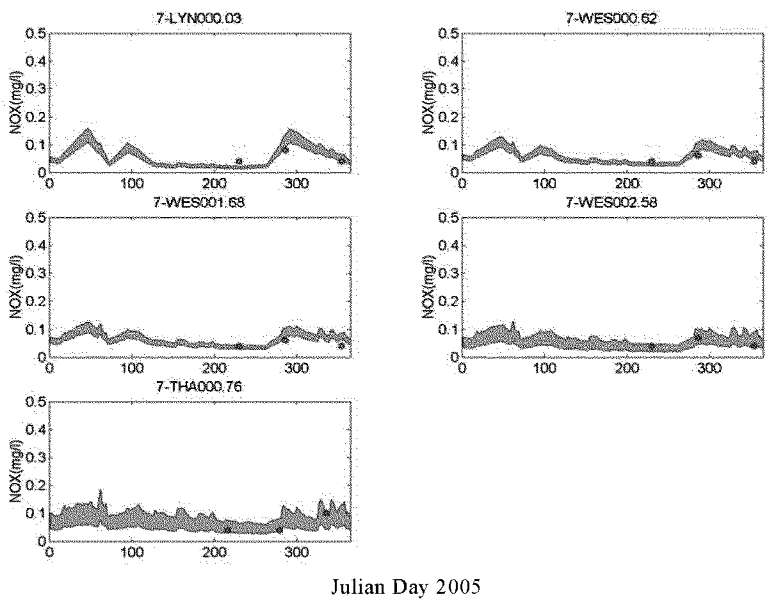
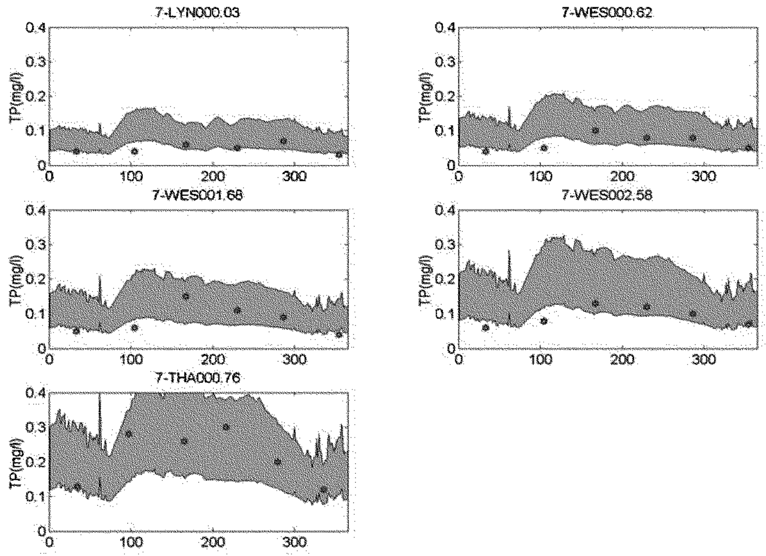
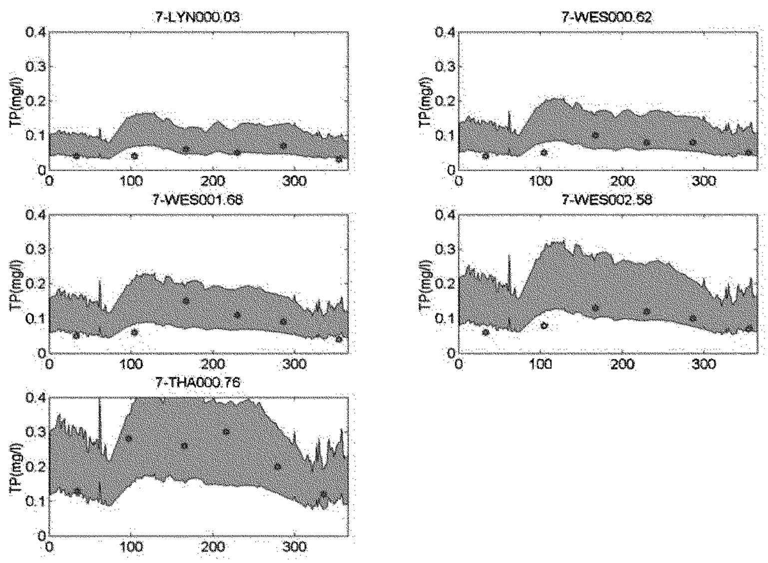


Figure VI.30. Predicted vs. observed nitrate-nitrite at Western Branch DEQ stations for 2005.



Julian Day 2004

Figure VI.31. Predicted vs. observed total phosphorus at Western Branch DEQ stations for 2004.



Julian Day 2005

Figure VI.32. Predicted vs. observed total phosphorus at Western Branch DEQ stations for 2005.

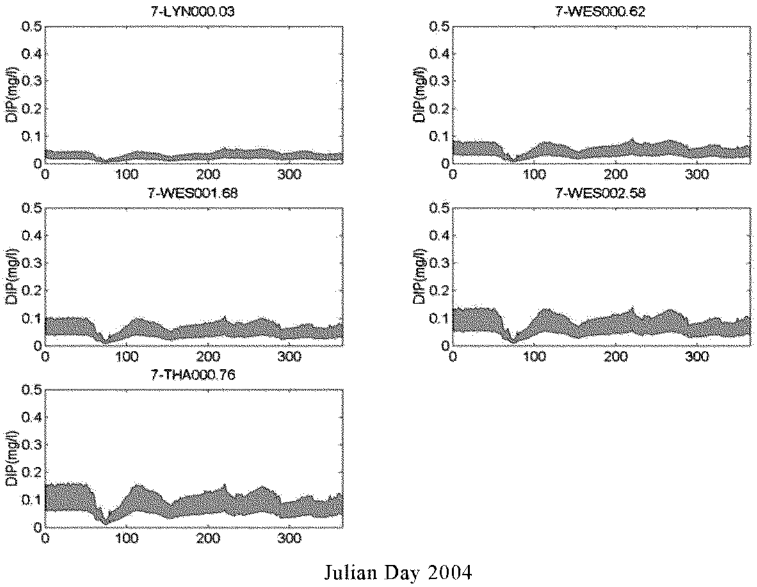


Figure VI.33. Predicted ortho-phosphorus at Western Branch DEQ stations for 2004.

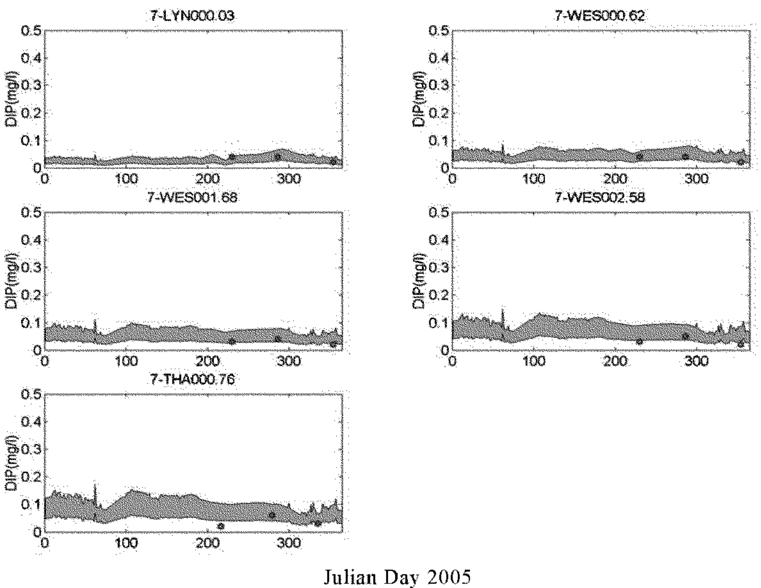


Figure VI.34. Predicted vs. observed ortho-phosphorus at Western Branch DEQ stations for 2005.

B. Eastern Branch DEQ stations validation results

As mentioned, the hydrological condition in 2004 and 2005 are different from those of 2006; between 2004 and 2005, the seasonal patterns also shifted differently. The year 2004 has a dry spring and wet summer whereas the year 2005 has a wet spring, but a dry summer. These conditions applied in the Western Brach as well as in the Eastern Branch. Water quality model validation results for Eastern Branch DEQ stations for 2004 and 2005 are carried out with different salinity patterns and the reaction constants that are temperature-dependent. Water quality model validation results for Eastern Branch DEQ stations for 2004 and 2005 are shown in Figures VI.35 through VI.48. In all figures comparing modeled and measured water quality parameters, the model predictions are represented as a gray band bounded by daily minimum and maximum.

Results for dissolved oxygen in 2004 and 2005, respectively, are shown in Figures VI.35 and VI.36. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen reasonably well, with only occasional over-prediction at the upstream stations of London Bridge (7-LOB001.79) Canal No. 2 (7-XBO001.30), and West Neck Creek (5BWNC010.02), in the latter part of each year. Figures VI.37 and VI.38 present the predicted versus observed comparisons for chlorophyll-a, catching the trend for all stations, but there are a few out-liers in the sparse observation data. Figures VI.39 and VI.40 show reasonable predicted results for 2004 and 2005, respectively, with good agreement with measured TKN values in latter 2005 (Figure VI.40). Predicted values for 2004-2005 ammonium for the Eastern Branch stations are shown in Figures VI.41 and VI.42. Despite some large diurnal fluctuations, these results appear to be reasonable, and agree well with the DEQ measurements taken in latter 2005 shown in Figure VI.42. Figures VI.43 and VI.44 show the 2004-2005 model predictions for nitrate-nitrite. Measured values of nitrate-nitrite in latter 2005 all fall within the daily min-max prediction range. Figures VI.45 and VI.46 show that, whereas total phosphorus predictions have a large diurnal range in the Eastern Branch, all observation data fall within this range. Lastly, the 2004-2005 ortho phosphorus predictions shown in Figures VI.47 and VI.48 appear reasonable and match the observation data shown in Figure VI.48 for latter 2005.

As was the case for the 2006 calibration data for Eastern Branch DEQ stations shown in Chapter V, an overall inspection of Figures VI.35 through VI.48 shows gradual increases of both chlorophyll-a and nutrients in moving from the Inlet upstream to West Neck Creek (5BWNC010.02), and a slight decrease in the summer of dissolved oxygen as seen moving upstream in the Eastern Branch. Overall, the responses in the Eastern Branch are very similar to those in the Western Branch, except that, at the very upstream stations, we consistently observe that Thalia Creek in the Western Branch has slightly, but consistently, higher TKN, NH_4, and chlorophyll values as compared to the stations at London Bridge, Canal No. 2, and West Neck Creek stations. That could contribute to a higher chance of forming localized low DO in the summer.

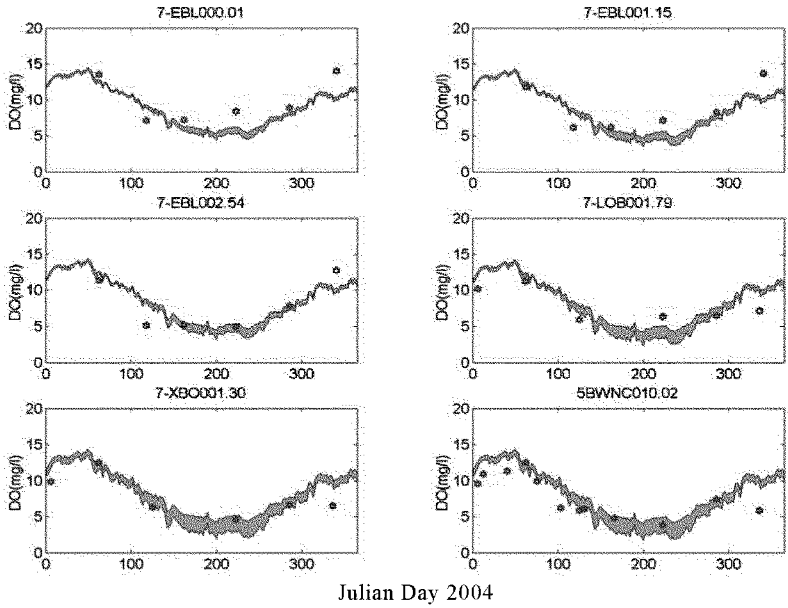


Figure VI.35. Predicted vs. observed dissolved oxygen at Eastern Branch DEQ stations for 2004.

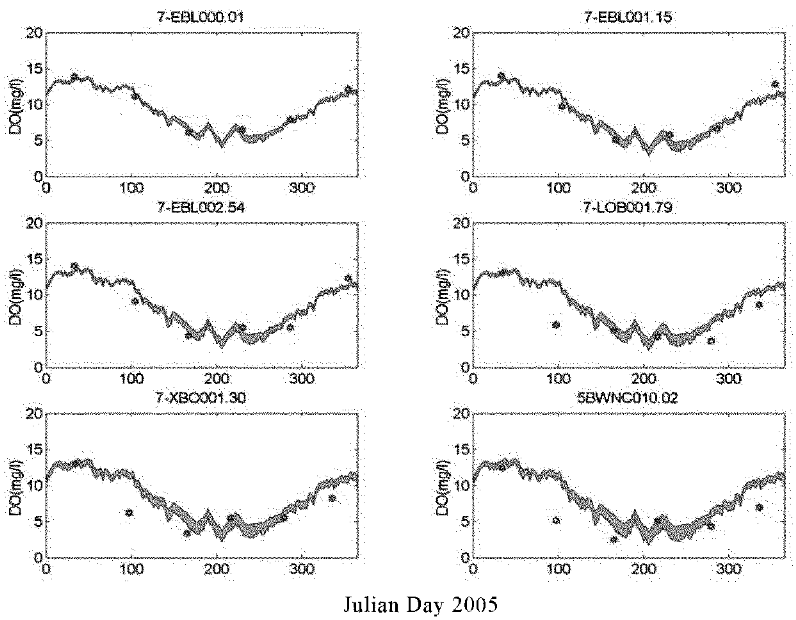


Figure VI.36. Predicted vs. observed dissolved oxygen at Eastern Branch DEQ stations for 2005.

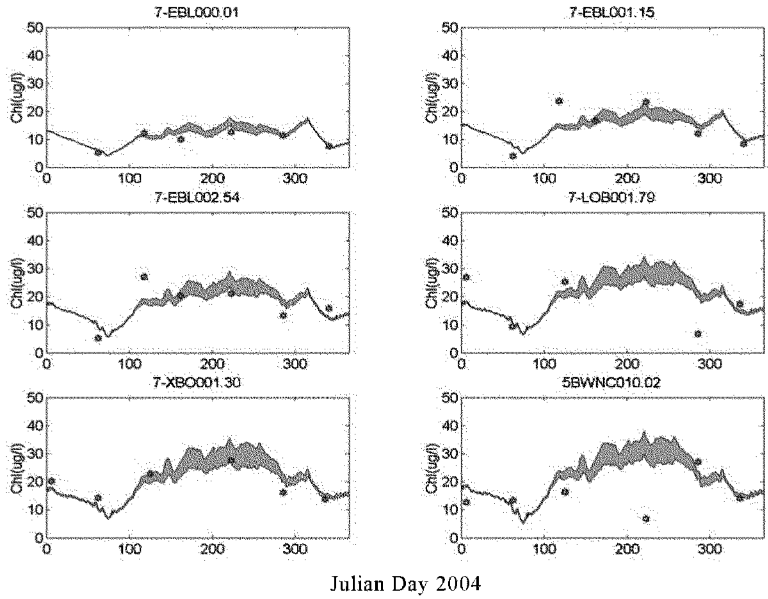


Figure VI.37. Predicted vs. observed chlorophyll-a at Eastern Branch DEQ stations for 2004.

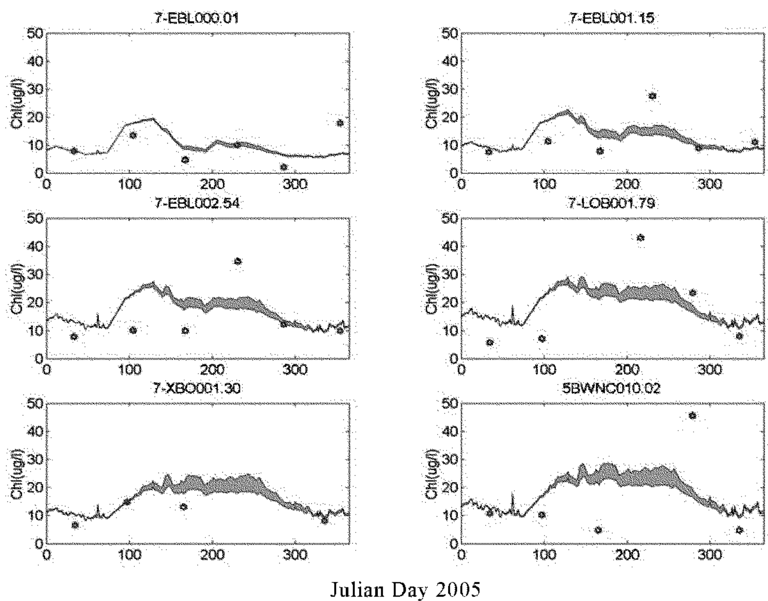


Figure VI.38. Predicted vs. observed chlorophyll-a at Eastern Branch DEQ stations for 2005.

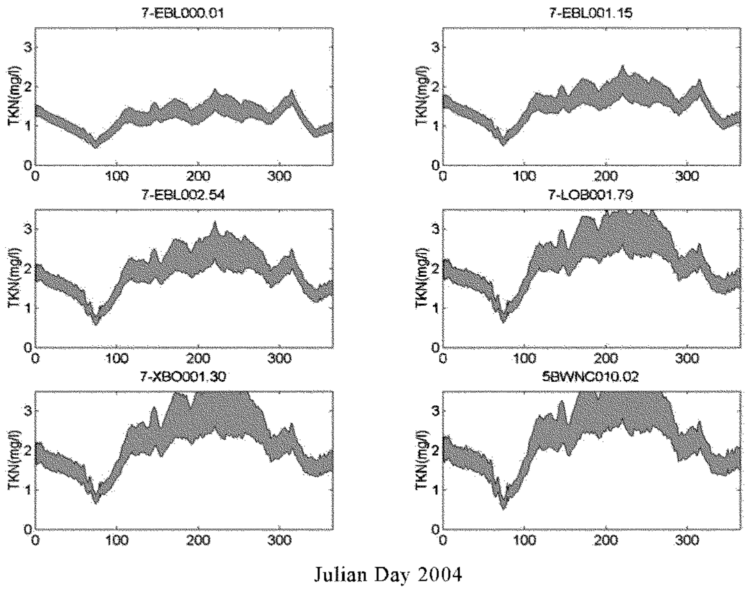


Figure VI.39. Predicted TKN at Eastern Branch DEQ stations for 2004.

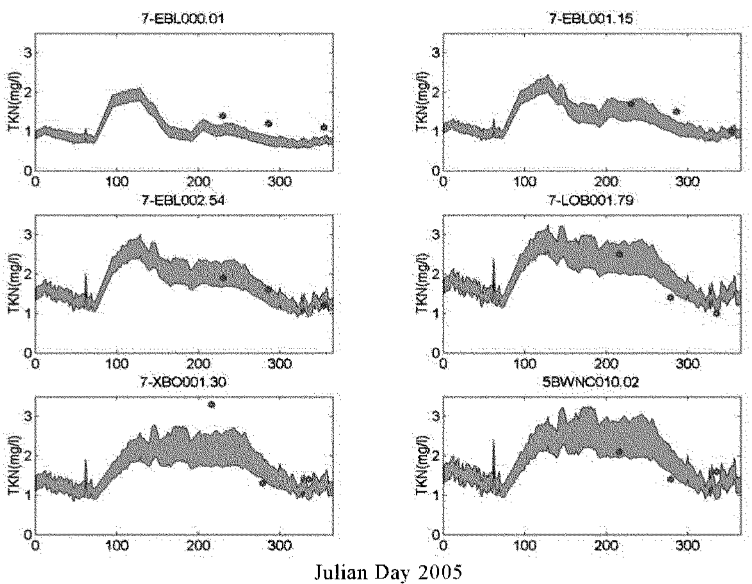


Figure VI.40. Predicted vs. observed TKN at Eastern Branch DEQ stations for 2005.

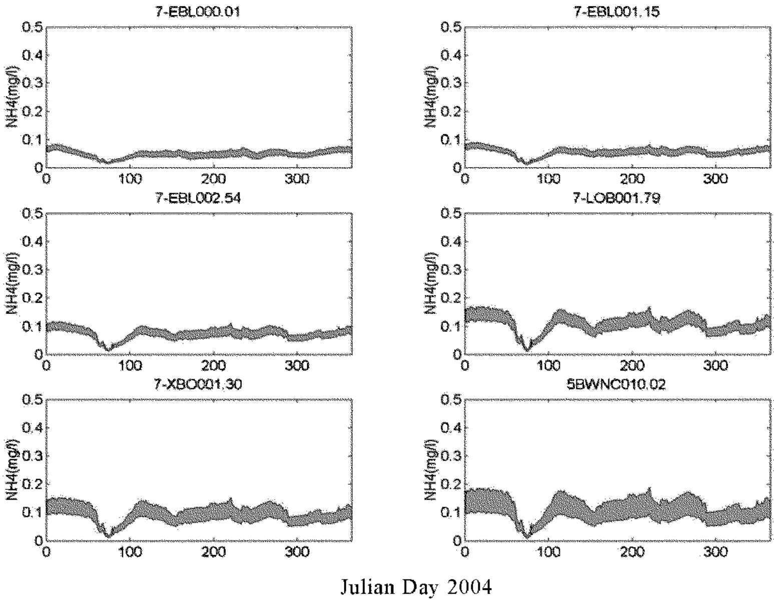


Figure VI.41. Predicted ammonium at Eastern Branch DEQ stations for 2004.

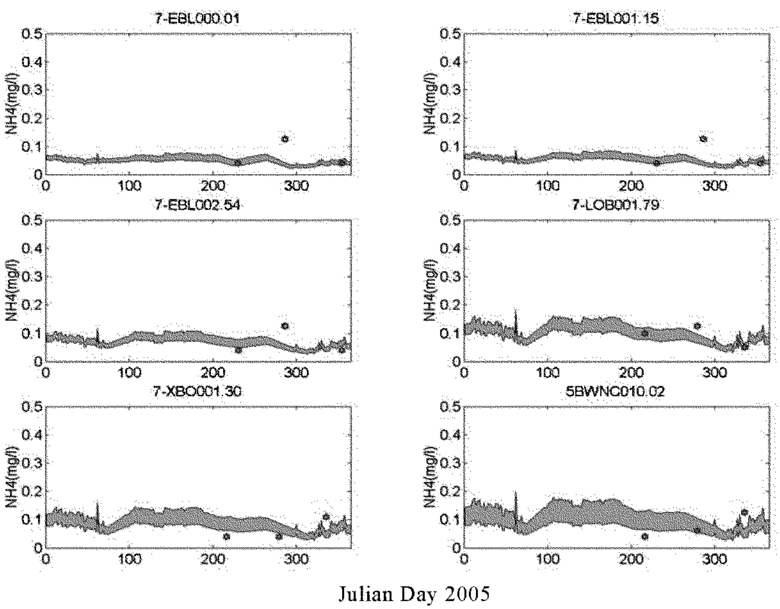


Figure VI.42. Predicted vs. observed ammonium at Eastern Branch DEQ stations for 2005.

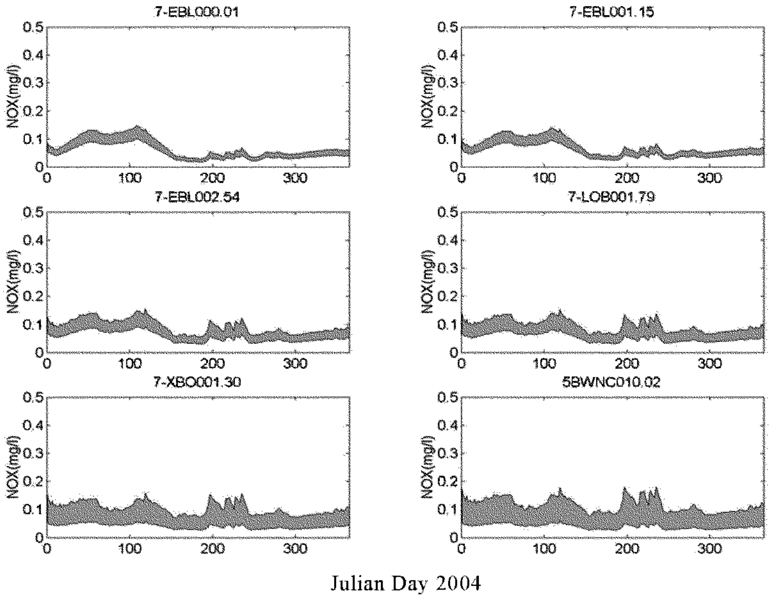


Figure VI.43. Predicted nitrate-nitrite at Eastern Branch DEQ stations for 2004.

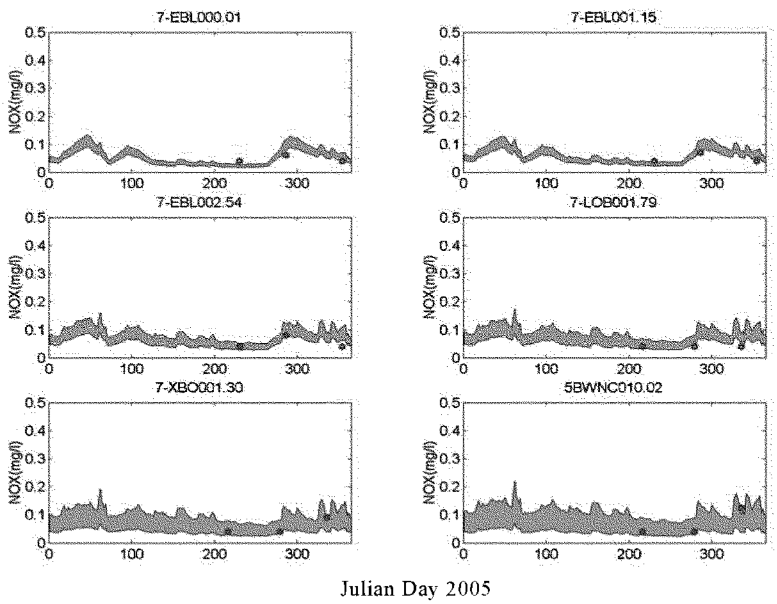


Figure VI.44. Predicted vs. observed nitrate-nitrite at Eastern Branch DEQ stations for 2005.

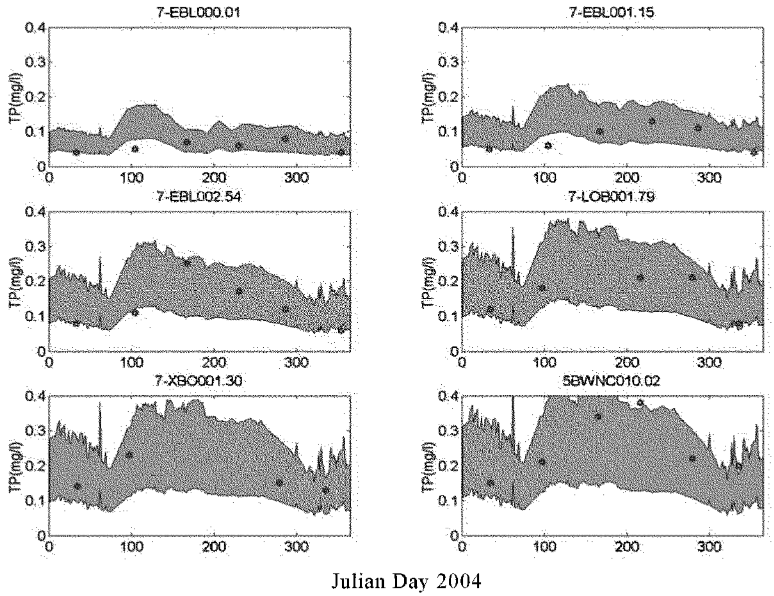


Figure VI.45. Predicted vs. observed total phosphorus at Eastern Branch DEQ stations for 2004.

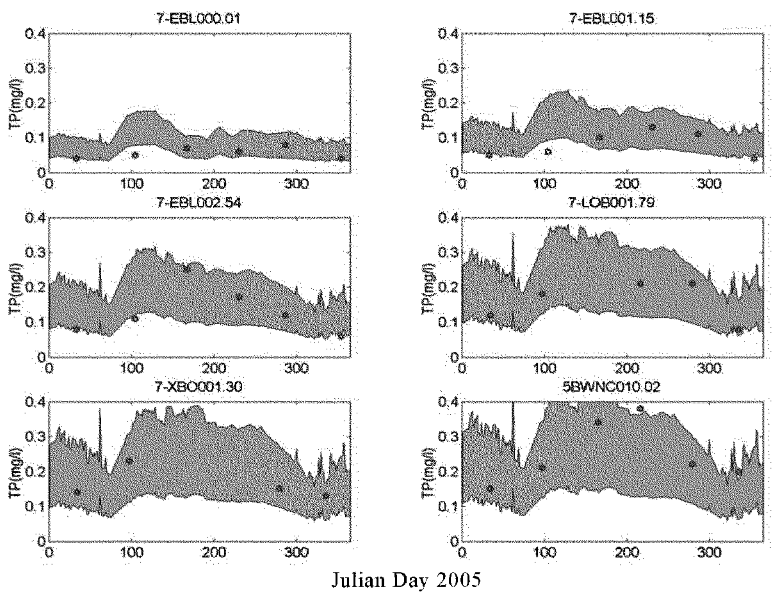


Figure VI.46. Predicted vs. observed total phosphorus at Eastern Branch DEQ stations for 2005.

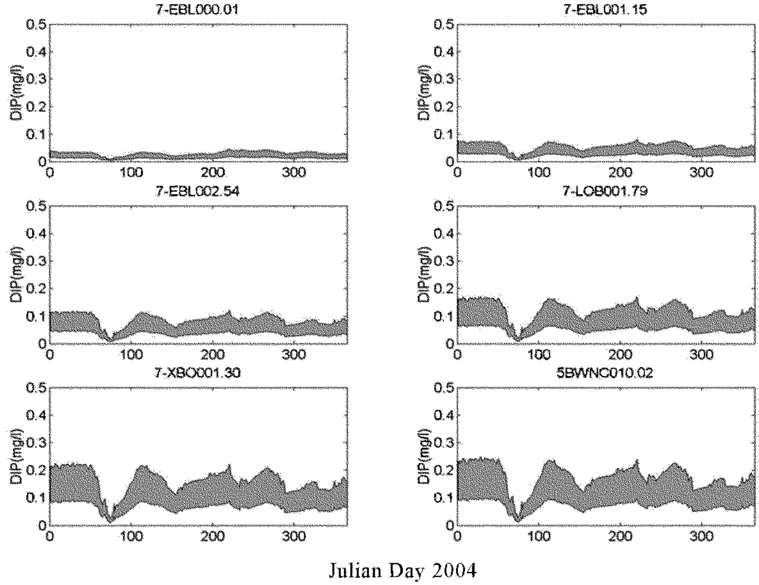


Figure VI.47. Predicted ortho phosphorus at Eastern Branch DEQ stations for 2004.

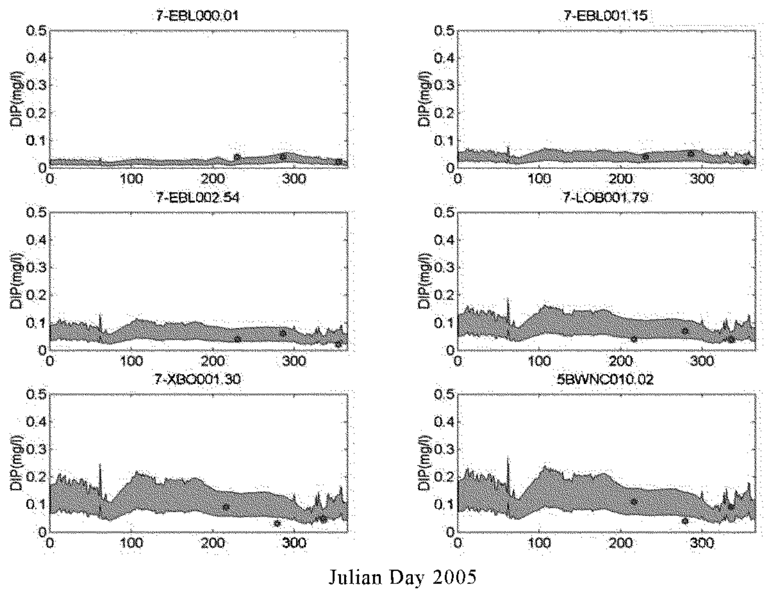


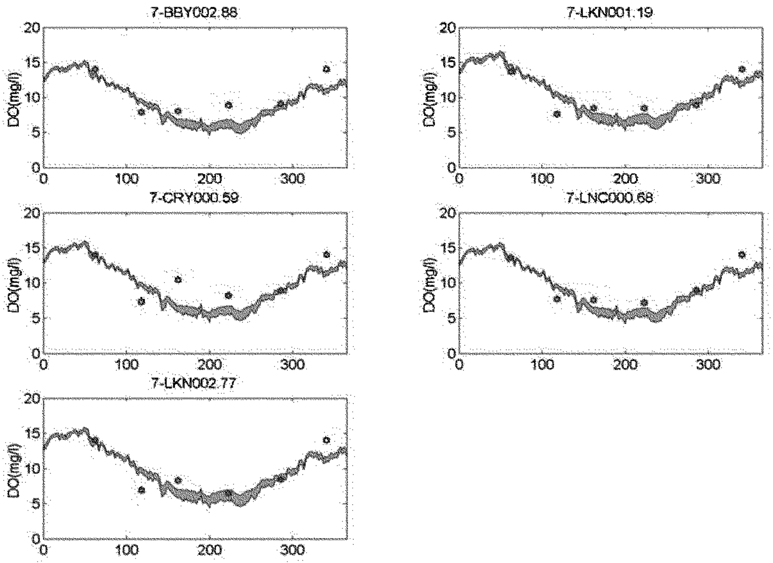
Figure VI.48. Predicted vs. observed ortho phosphorus at Eastern Branch DEQ stations for 2005.

C. Broad Bay / Linkhorn Bay Branch DEQ stations validation results

In the past two sections, we have emphasized that the hydrological conditions in 2004 and 2005 are different from those in 2006. In addition, the year 2004 had a dry spring and wet summer whereas the year of 2005 had a wet spring, but a dry summer. These conditions apply in the Western and Eastern Branches, but do not seem to affect Broad Bay and Linkhorn Bay as much. This is likely because the freshwater inputs in the Broad Bay and Linkhorn Bay are less than those in Eastern and Western Branches and, therefore, the loading was not the single most important reason for the temporal and spatial variability.

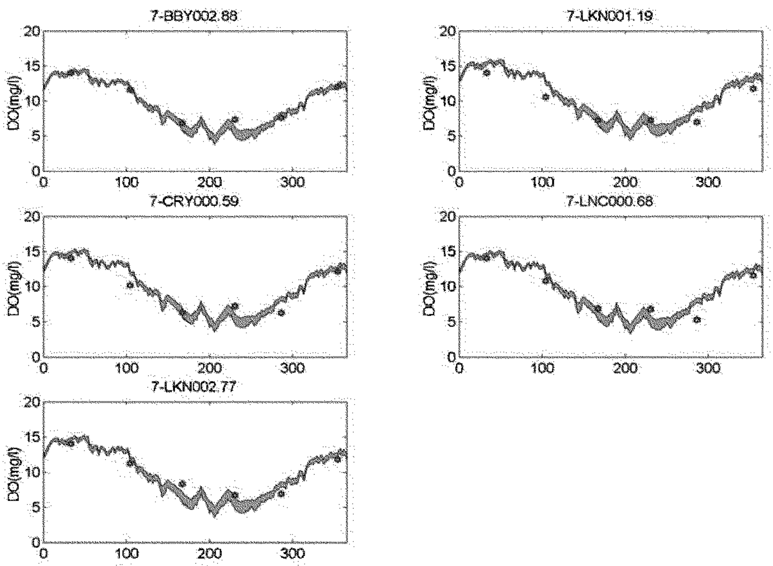
Water quality model validation results for Broad Bay/Linkhorn Bay Branch DEQ stations for 2004 and 2005 are carried out with different salinity patterns and the reaction constants that are temperature-dependent. Water quality model validation results for Broad Bay / Linkhorn Bay Branch DEQ stations for 2004 and 2005 are shown in Figures VI.49 through VI.62. In all figures comparing modeled and measured water quality parameters, the model predictions are represented as a gray band bounded by daily minimum and maximum.

Validation results for the comparison of modeled versus measured dissolved oxygen in 2004 and 2005 at Broad and Linkhorn Bay Branch DEQ stations are shown, respectively, in Figures VI.49 and VI.50. As illustrated, the model reproduces the observed temporal distribution of dissolved oxygen extremely well at all 5 DEQ stations in this branch for both years. Figures VI.51 and VI.52 show reasonably good agreement overall between predicted and observed values for chlorophyll-a. Figures VI.53 and VI.54, respectively, show model predictions for 2004 and 2005 for TKN at all Broad Bay and Linkhorn Bay stations, and a good agreement between modeled and measured TKN values can be seen for latter-2005 in Figure VI.54. The 2004 and 2005 predicted values of ammonium are shown in Figures VI.55 and VI.56, respectively, and show good agreement with observations taken in the latter part of 2005 (Figure VI.56). Figures VI.57 and VI.58 show predictions of nitrate-nitrite by the model and match well with available nitrate-nitrite data from latter 2005 (Figure VI.58). Figures VI.59 and VI.60 show that total phosphorus predictions from the model agrees reasonably well with observations at all stations with a slight tendency to over-predict at upstream stations. The model predictions of ortho phosphorus for 2004 and 2005 shown in Figures VI.61 and VI.62 appear reasonable and match the observations available in late 2005 shown in Figure VI.62. Finally, inspection of Figures VI.49 through VI.62 shows that there is almost no spatial decrease in dissolved oxygen nor increase in chlorophyll-a in moving from the Inlet upstream to the head of Linkhorn Bay, similar to what was found for the 2006 calibration data presented in Chapter V. Overall, the Broad Bay and Linkhorn Bay have lower higher TKN, NH_4, TP, and Chlorophyll values as compared to those in the Western and Eastern Branches. Hypoxic conditions in this branch are rare occurrences. On a parallel effort, however, there is evidence that the Mill Dam Creek on the southern shore of Broad Bay can occasionally discharge high concentrations of nitrogen and phosphorus into the system. That is beyond the scope of this study.



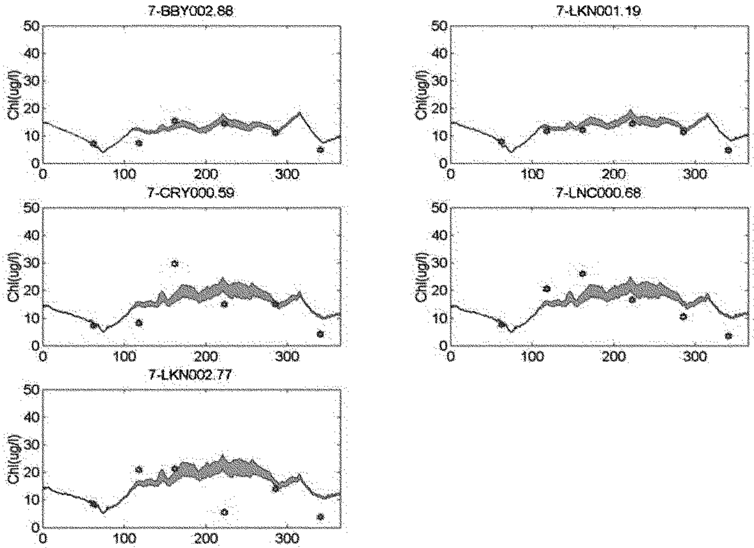
Julian Day 2004

Figure VI.49. Predicted vs. observed dissolved oxygen at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.



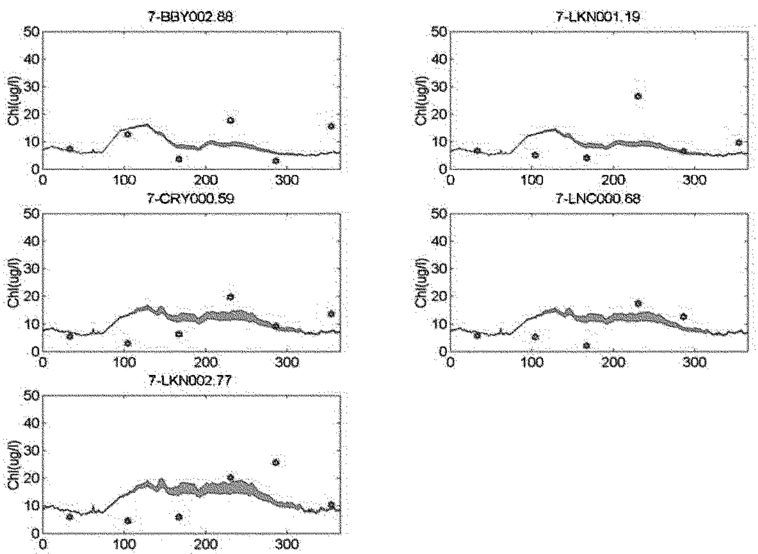
Julian Day 2005

Figure VI.50. Predicted vs. observed dissolved oxygen at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.



Julian Day 2004

Figure VI.51. Predicted vs. observed chlorophyll-a at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.



Julian Day 2005

Figure VI.52. Predicted vs. observed chlorophyll-a at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

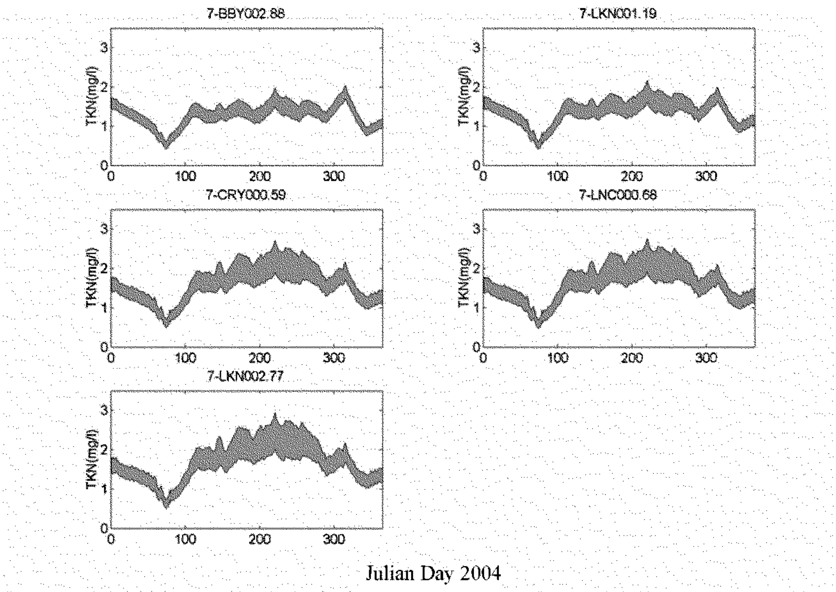


Figure VI.53. Predicted TKN at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

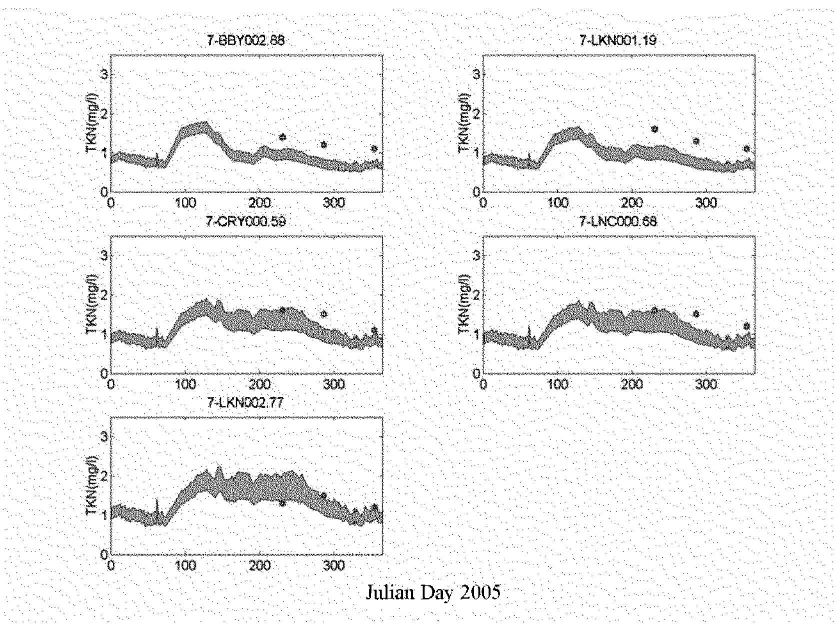


Figure VI.54. Predicted vs. observed TKN at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

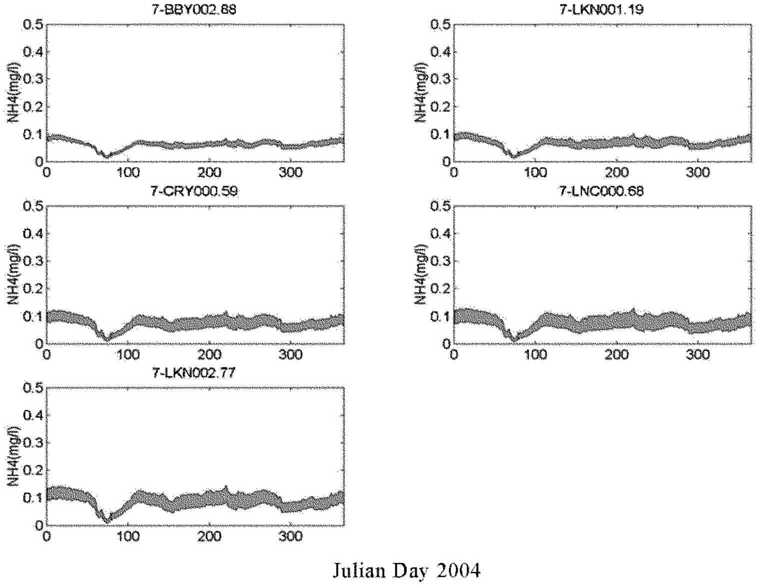


Figure VI.55. Predicted ammonium at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

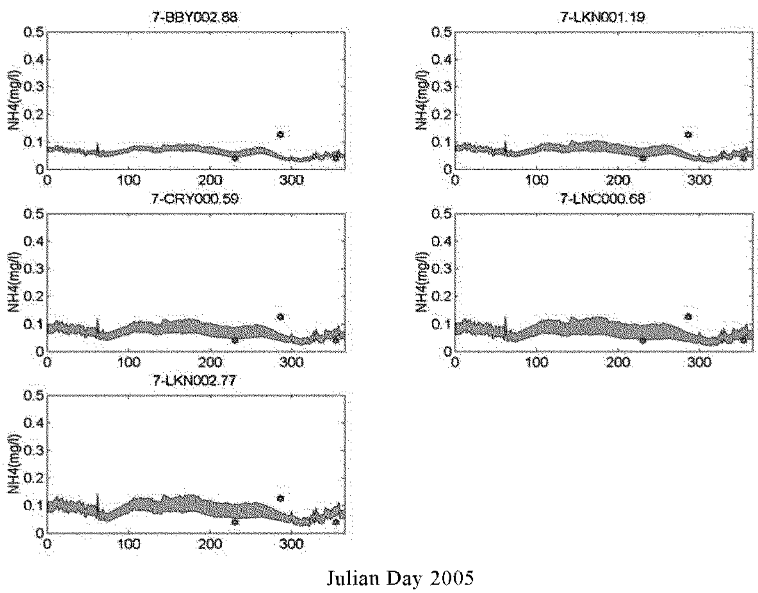


Figure VI.56. Predicted vs. observed ammonium at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

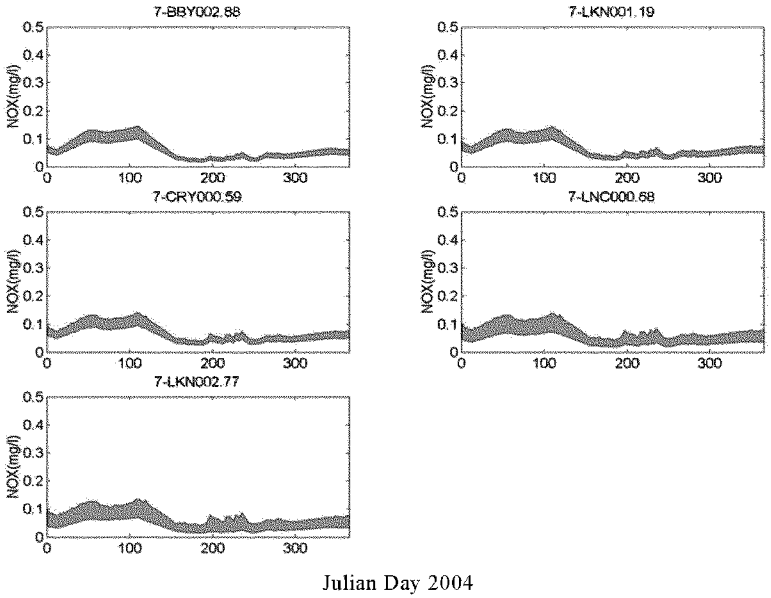


Figure VI.57. Predicted nitrate-nitrite at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

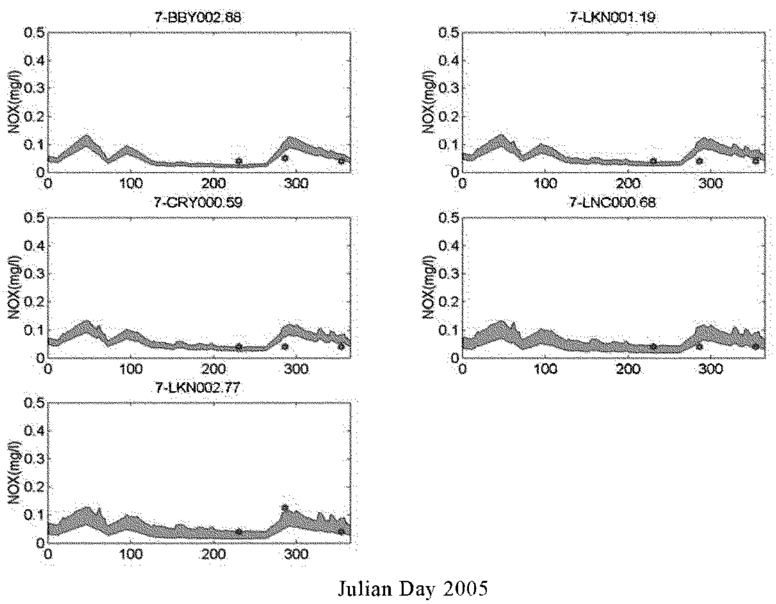


Figure VI.58. Predicted vs. observed nitrate-nitrite at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

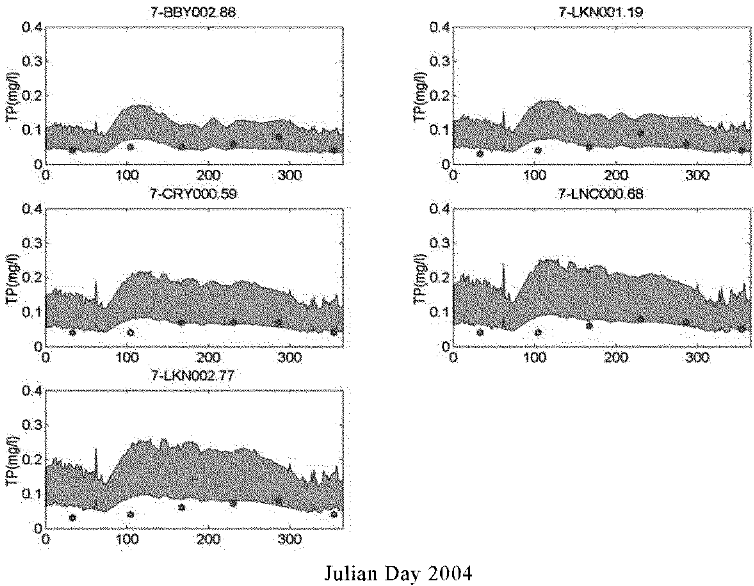


Figure VI.59. Predicted vs. observed total phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

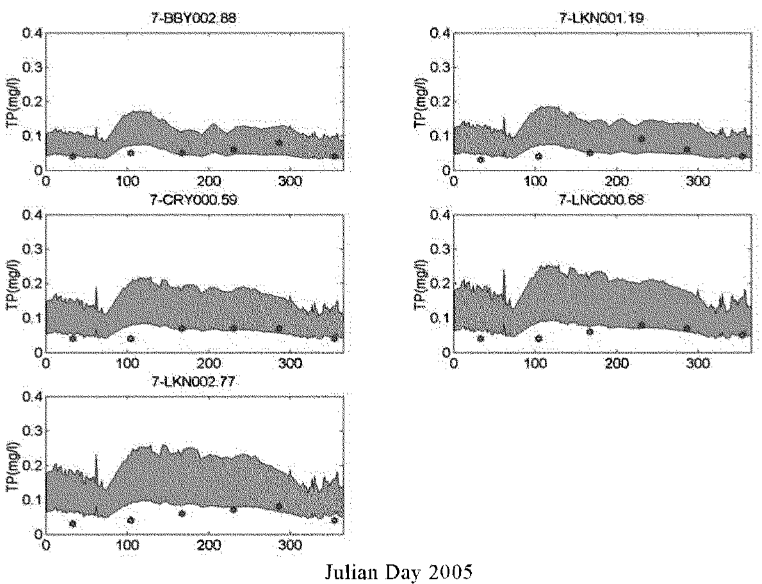


Figure VI.60. Predicted vs. observed total phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

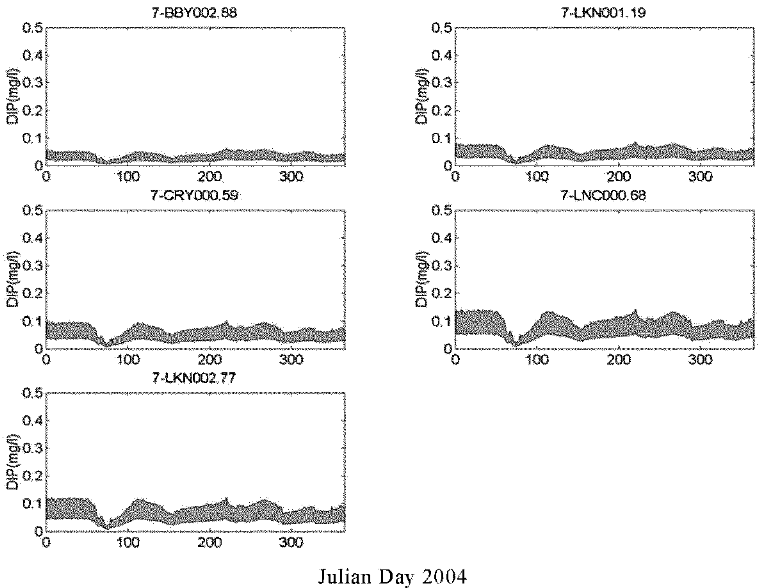


Figure VI.61. Predicted ortho phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

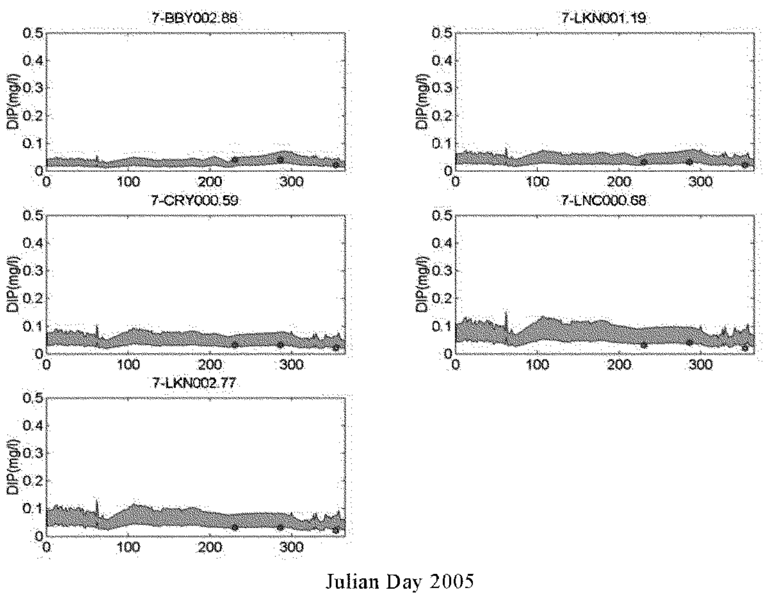


Figure VI.62. Predicted vs. observed ortho phosphorus at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

Summary Statistics of Water Quality Model Validation Results

In the previous portion of this section, qualitative comparisons between model results and observed values were presented. As in the case for the model calibration results shown in Chapter V, although the comparisons indicate that the CE-QUAL-ICM water quality model can reproduce the physical, chemical, and biological processes that affect the eutrophication process in the Lynnhaven River, a more specific measure of the model performance is desirable.

In order to provide a more quantifiable measure of the performance of the water quality model during the validation process, a statistical analysis is applied to the comparisons of predicted and observed data of the water quality validation results for 2004 and 2005. Error measurement parameters for these comparisons (i.e., mean error, absolute mean error, root-mean-square error, and relative error) are fully described in Chapter V, which shows the analysis of the performance of the model during calibration.

Additionally, 1:1 plots of predicted results vs. observations show visually how well the model predictions compare with observations and whether the model shows a bias towards either over-prediction or under-prediction.

A. Statistical Analysis of Dissolved Oxygen, Chlorophyll-a, TKN, and Total Phosphorus Results

Statistical analysis of 7 key water quality parameters was performed by comparing predicted and observed results of each parameter for all of the 16 Lynnhaven DEQ stations combined. The every-other-month DEQ measurements taken in 2004 and 2005 thus provided sample sizes of 185, 179, 45, and 18, respectively, for DO, chl-a, TKN, and TP predicted vs. observed comparisons at all Lynnhaven River DEQ stations. The error measures for these 4 comparisons are shown in Table VI.1 below and their corresponding 1:1 plots are shown in Figure VI.63. Overall, predicted and observed DO values compare well. The median value for mean error is about -0.07 mg/l while the absolute mean error is 1.10 mg/l. The root-mean-square error for both surface and bottom DO is about 1.44 mg/l, whereas the relative error is around 12%. It is noted that these statistics compare well with those for the 2006 calibration and that they are comparable to other eutrophication model studies such as the Three-dimensional Eutrophication Model Study of the Chesapeake Bay (Cerco and Cole, 1994).

It was also worthwhile to point out that the absolute mean error and root-mean-square error of water quality parameters shown in Table VI.1 are well within the range of natural variation in a given season of measurements when compared with available observations, for example, Figures VI.21-VI.26, V1.31-VI.32, VI.35-VI.40, VI.45-VI.46, VI.49-VI.54, and VI.59-VI.60.

Table VI.1. Statistical summary of errors derived by comparing predicted vs. observed surface values of DO, chl-a, TKN, and TP for years 2004 - 2005.

Predicted vs. Observed Dissolved Oxygen, Chlorophyll-a, TKN, and Total Phosphorus				
	All 16 Lynnhaven DEQ Stations			
Parameter:	DO	Chl-a	TKN	TP
Sample size	185	179	45	18
Mean Error	-0.07	0.60	0.13	-0.04
Absolute Mean Error	1.10	5.17	0.26	0.05
RMS Error	1.44	10.38	0.30	0.06
Relative Error	0.12	0.36	0.18	0.49
Corr. Coeff. (r)	0.89	0.79	0.80	0.85

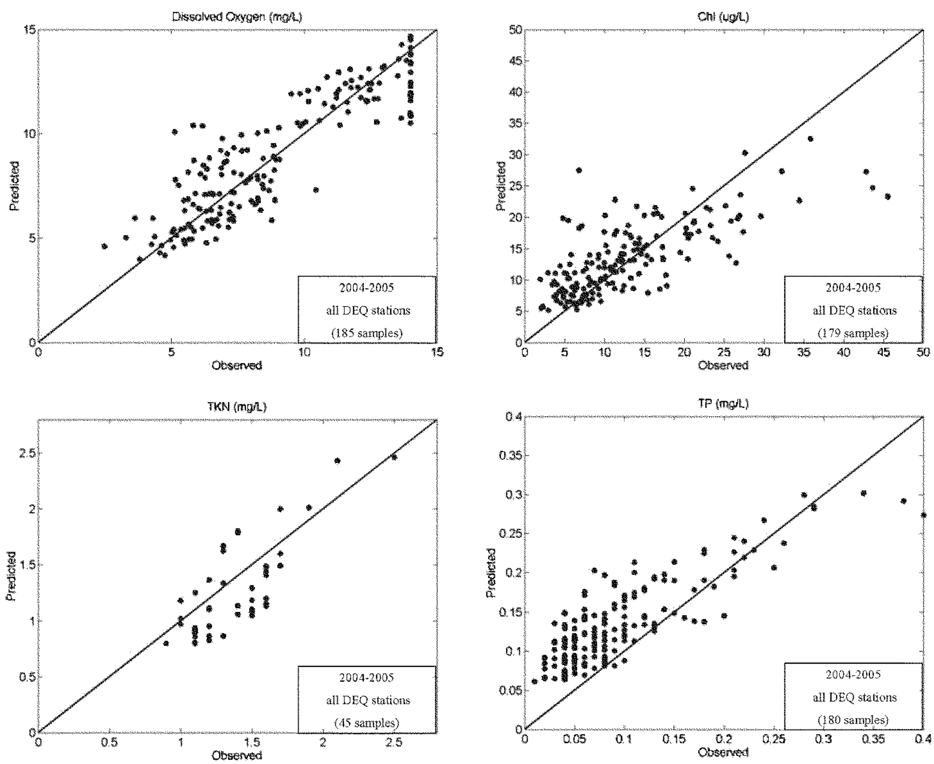


Figure VI.63. Plots of 1:1 predicted vs. observed DO, chl-a, TKN, and TP at all 16 Lynnhaven DEQ stations for 2004 - 2005.

B. Statistical Analysis of Ammonia, Nitrate-Nitrite, and Dissolved Inorganic Phosphate

To quantify the comparison between predicted and observed values NH_4, NO_x, and DIP, determination of statistical errors and construction of 1:1 plots were performed for these parameters as well. Table VI.2 below shows error values of each parameter for predicted vs. observed comparisons of all 16 Lynnhaven DEQ stations combined for 2004 and 2005.

The nitrogen and phosphorus are major nutrients that can be used for photosynthesis. In particular, NH_4, NO_x, and dissolved phosphorus are species that can be uptaken directly by the phytoplankton. Therefore, they are important indicator for the environmental quality. Nitrogen's concentration is usually higher than phosphorus. The 1:1 plots of predicted vs. observed comparisons of NH_4, NO_x, and DIP are shown in Figure VI.64. The absolute mean error and root-mean-square error of these water quality parameters show that the differences between model predictions and observations are within the range of natural variation in a given season of measurements when compared with available observation, for example, Figures VI.27-VI.30, VI.33-VI.34, VI.41-VI.44, VI.47-VI.48, VI.55-VI.58, and VI.61-VI.62.

Table VI.2. Statistical summary of errors derived by comparing predicted vs. observed values of NH_4, NO_X, and DIP for all 16 Lynnhaven DEQ stations for 2004 - 2005.

Parameter:	NH_4	NO_X	DIP
Sample Size	45	45	45
Mean Error	0.00	-0.01	-0.02
Absolute Mean Error	0.03	0.02	0.02
RMS Error	0.04	0.02	0.02
Relative Error	0.48	0.42	0.47
Corr. Coeff. (r)	0.22	0.58	0.70

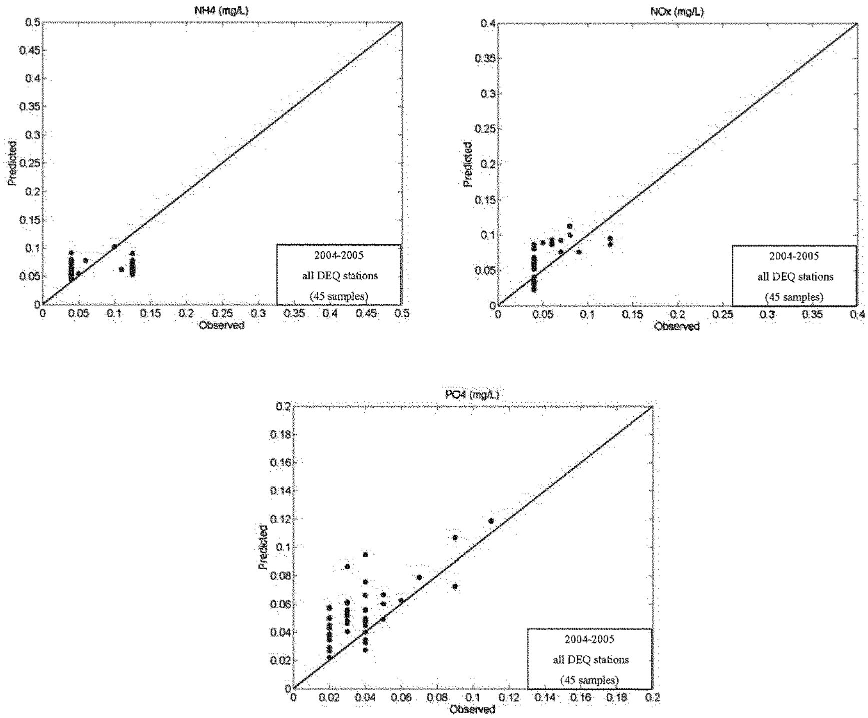


Figure VI.64. Plots of 1:1 predicted vs. observed NH_4, NO_x, and DIP TP at all 16 Lynnhaven DEQ stations for 2004 - 2005.

VI-3 Validation of the Sediment Transport Model

For validation of the sediment transport model, two observation datasets were utilized:

1) High-frequency, continuously measured turbidity time series data from 3 VIMS deployments in 2005 were used to validate the sediment transport model, based on a derived correlation between turbidity and TSS. Station locations for these 3 deployments are shown in Figure VI.65. Comparisons of the modeled TSS values and those derived from these high-frequency turbidity measurements are shown in Figure VI.66. Whereas the magnitudes of the modeled sediment concentration generally agreed with those derived from turbidity measurements, detailed variations did not completely match, probably due to the uncertainty between observed turbidity and TSS.

2) To confirm the model performance over the full spatial domain, predictions from model simulations for both 2004 and 2005 were used to compare to DEQ data at all 16 Lynnhaven stations. These comparisons are shown in Figures VI.67-VI.68, VI.69-VI.70, and VI.71-VI.72, respectively, for the Western, Eastern, and Broad Bay/Linkhorn Bay Branch DEQ stations of the Lynnhaven.

Inspection of Figures VI.67 through VI.72 shows that the model, in general, reproduced TSS concentrations at all stations reasonably well. It should be noted that no parameters were altered for the simulations of validation years 2004 and 2005.

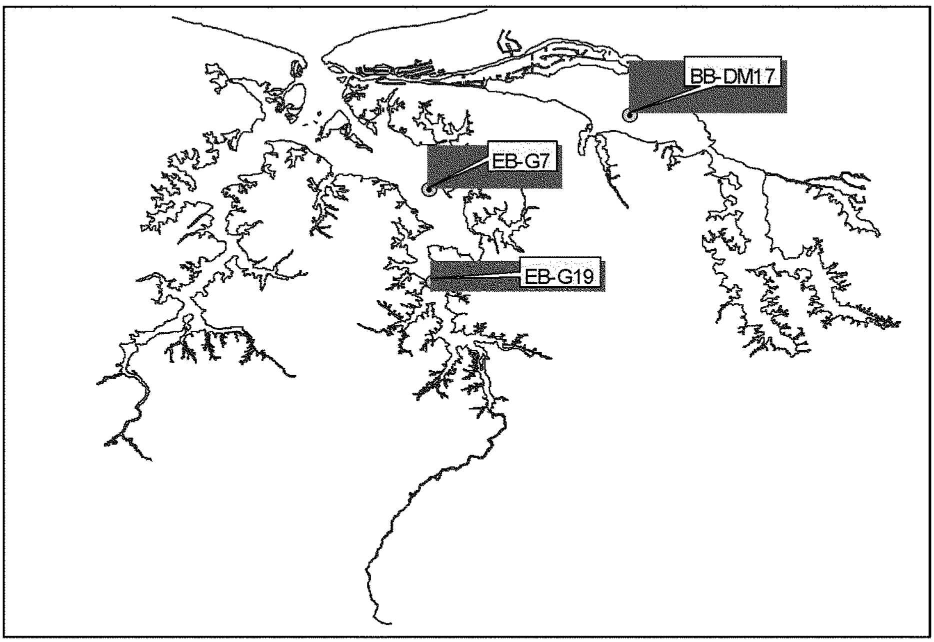
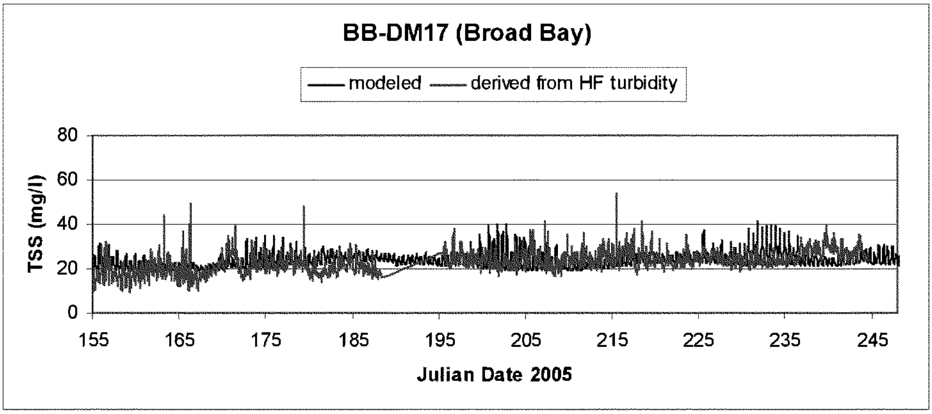
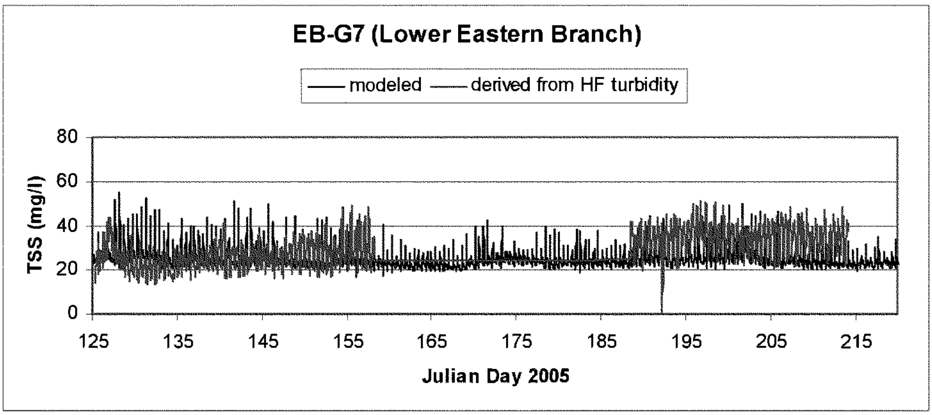


Figure VI.65. Station locations for high-frequency measurements of turbidity in 2005 in the Lynnhaven River system.





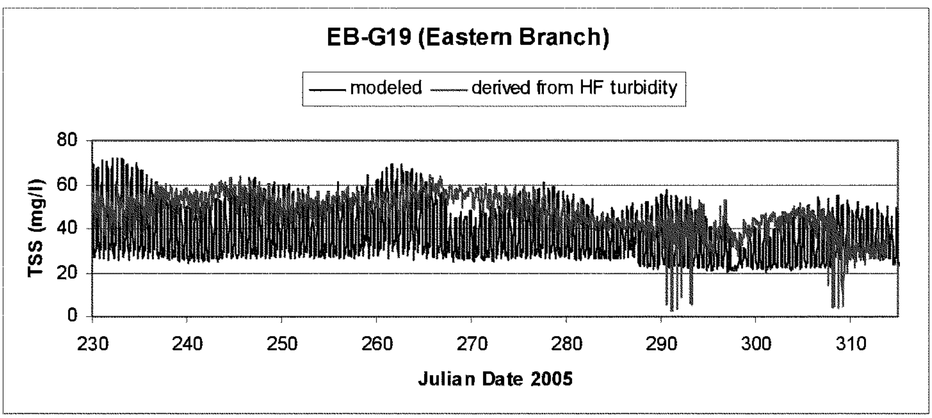
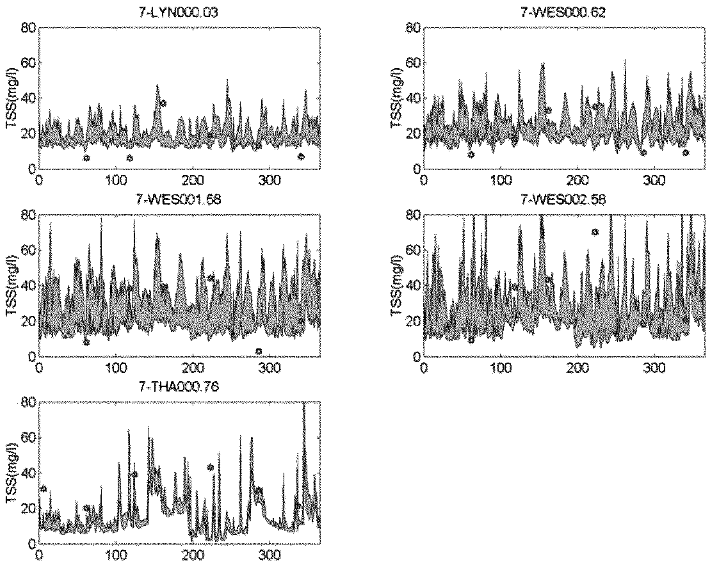
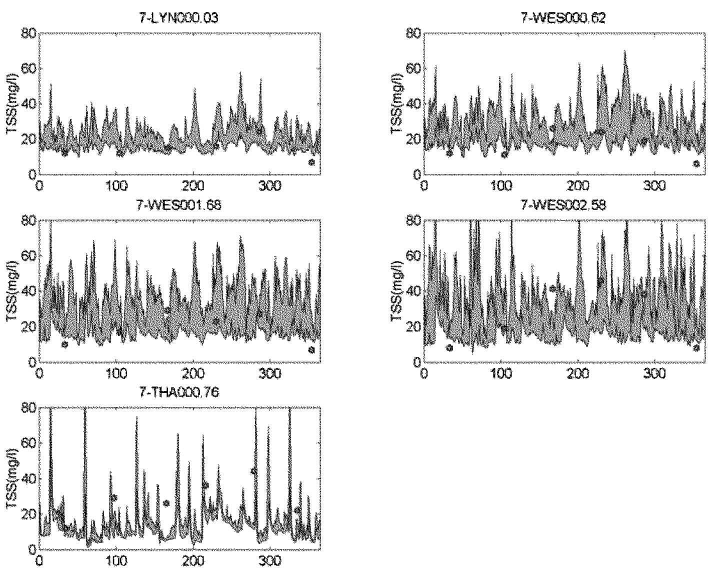


Figure VI.66. Predicted TSS vs. TSS derived from high-frequency turbidity measurements at 3 locations in the Lynnhaven in 2005.



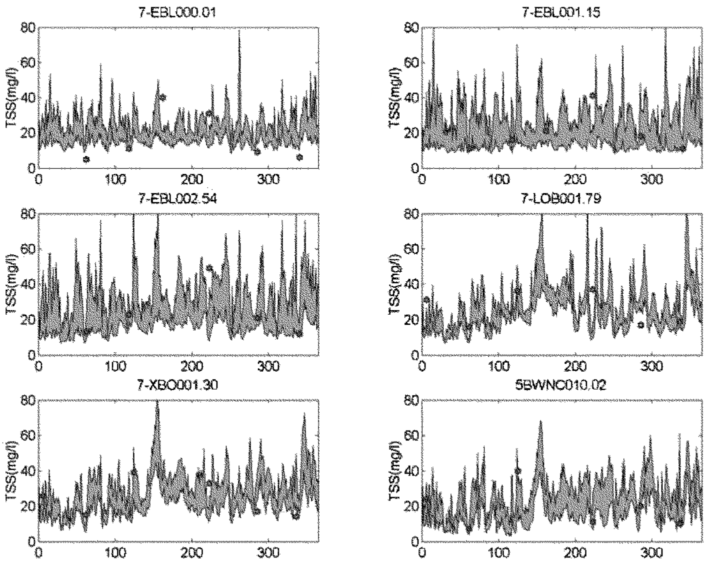
Julian Date 2004

Figure VI.67. Predicted vs. observed TSS at Western Branch DEQ stations for 2004.



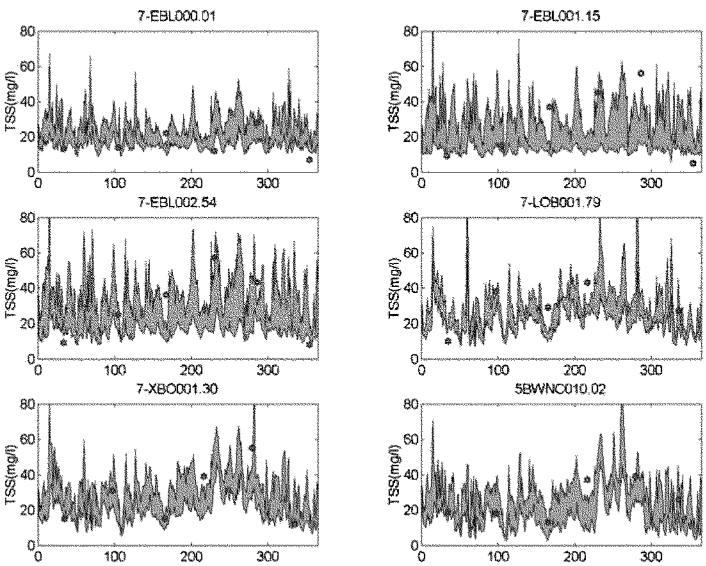
Julian Date 2005

Figure VI.68. Predicted vs. observed TSS at Western Branch DEQ stations for 2005.



Julian Date 2004

Figure VI.69. Predicted vs. observed TSS at Eastern Branch DEQ stations for 2004.



Julian Date 2005

Figure VI.70. Predicted vs. observed TSS at Eastern Branch DEQ stations for 2005.

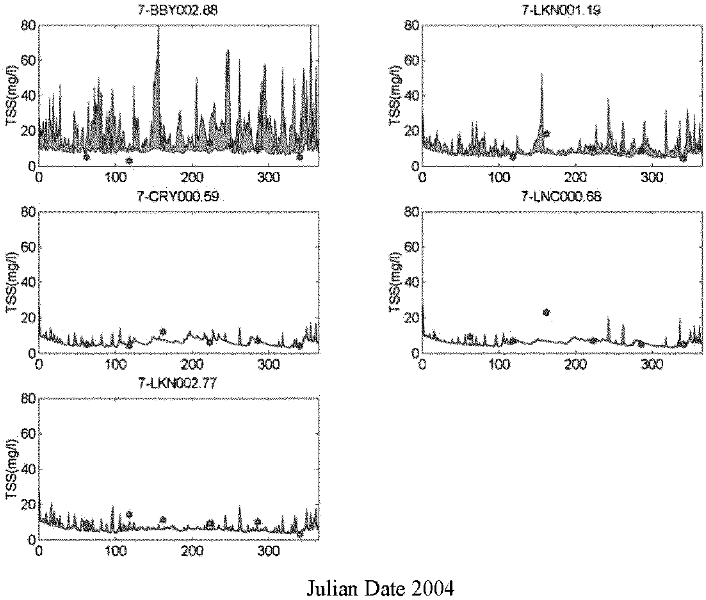


Figure VI.71. Predicted vs. observed TSS at Broad Bay / Linkhorn Bay Branch DEQ stations for 2004.

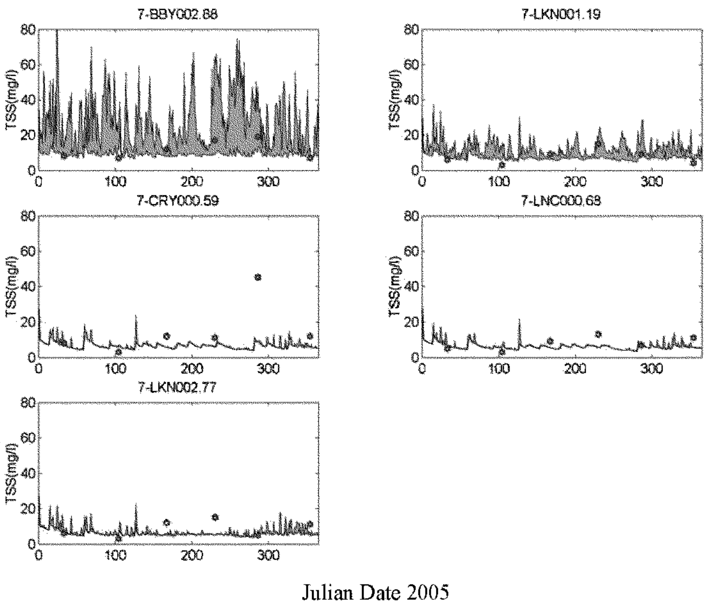


Figure VI.72. Predicted vs. observed TSS at Broad Bay / Linkhorn Bay Branch DEQ stations for 2005.

CHAPTER VII. SENSITIVITY ANALYSIS ON BENTHIC MICROALGAE DYNAMICS

The shallow water region (SWR) of coastal marine ecosystems, such as the Lynnhaven River system with depths less than 3-5 meters, encompasses the land-water margin and serves as the buffer zone for the transport of nutrients between land and water. When light can penetrate through the water column and reach the bottom, it triggers benthic microalgae (BMA) to perform photosynthesis, resulting in oxygen and nutrient benthic-pelagic exchange fluxes. BMA and their consumers are essential components of the Lynnhaven ecosystem; they uptake more nutrients and are more labile than vascular plants, and thus are clearly a source for fueling secondary primary production.

VII-1 Benthic Microalgae Model Formulation

The present model framework for benthic microalgae was inspired by the previous studies by Cerco and Seitzinger (1997) and Blackford (2002). The key variables determining the biomass of BMA are irradiance at the sediment surface, the self-shading of BMA, nutrients in the water column and sediment concentration, temperature, metabolism, and grazing rate. Figure VII.1 presents the conceptual diagram of the BMA model. BMA dynamics influence several biochemical processes: oxygen and nutrient fluxes between the water column and sediments, oxic layer thickness in the sediment, and the particulate organic material concentration in the sediment. All these processes have been built into the CE-QUAL-ICM model for its application to the Lynnhaven River system.

VII-1-1 Modeling biomass of BMA

BMA reside in a thin layer between the water column and sediments and its biomass is determined by the balance of production, respiration, and predation:

$$\frac{\delta B}{\delta t} = (P - BM - PR)B \qquad \text{(VII-1)}$$

where:
B = BMA biomass, as carbon (gm C m^{-2})
P = production rate (d^{-1})
BM = basal metabolism (respiration) rate (d^{-1})
PR = predation rate (d^{-1})

The production (growth) was determined by available light, nutrients, and ambient temperature:

$$P = P^B m * f(I) * f(N) * f(T) \qquad \text{(VII-2)}$$

where:
$P^B m$ = maximum production rate under optimal conditions (g C g^{-1} Chl d^{-1})

f(I) = effect of suboptimal light conditions
f(N) = effect of limited nutrient availability
f(T) = effect of temperature

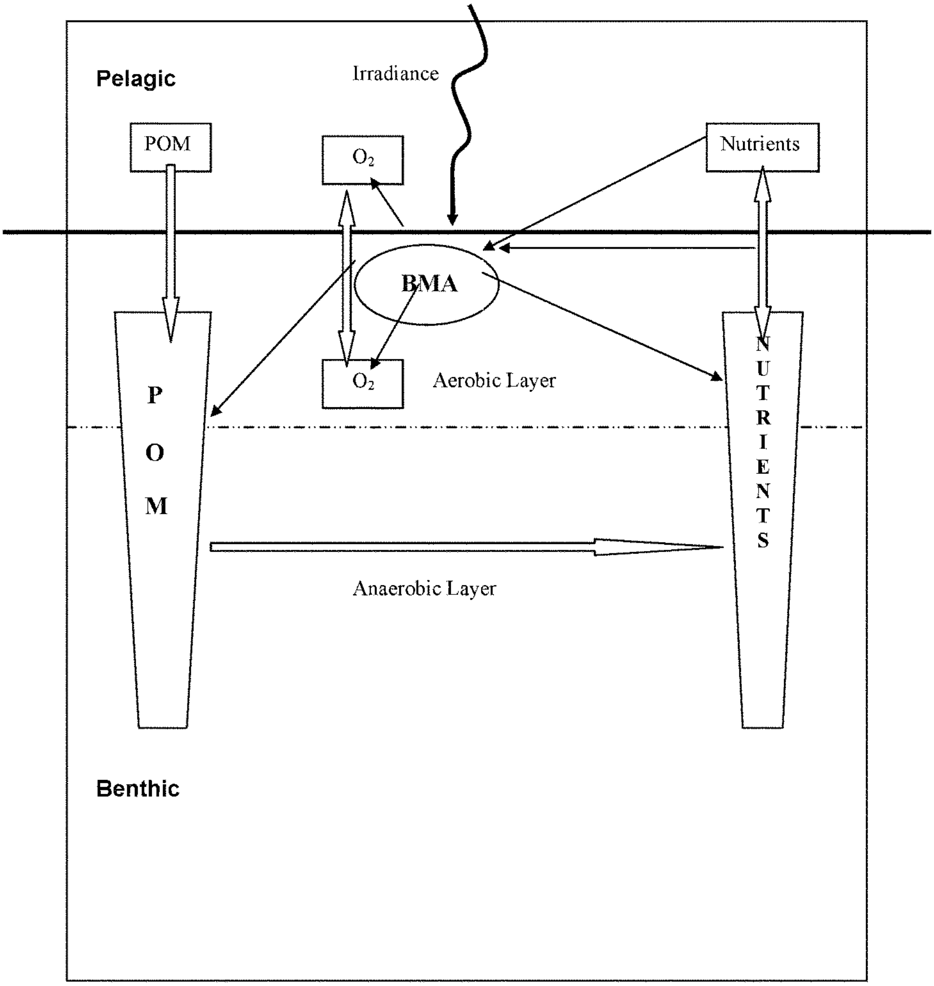


Figure VII.1. Framework of benthic algae model.

Light effect

Available light for BMA photosynthesis is the key factor to control the biomass of BMA. For example, the BMA biomass variability in the Southeastern Kattegat is 70% controlled by light availability (Sundbäck, 1984). The effect of light on production is expressed as:

$$f(I) = \frac{I}{\sqrt{I^2 + IK^2}} \qquad \text{(VII-3)}$$

where:
I = local irradiance

As is done for phytoplankton, the parameter Ik is defined as the irradiance at which the initial slope of the production vs. irradiance relationship intersects the value of P^Bm:

$$IK = \frac{P^B m}{\alpha} \qquad \text{(VII-4)}$$

where:
α = initial slope of production vs. irradiance relationship (g C g^{-1} Chl (E $m^{-2})^{-1}$)

Local irradiance varies within the BMA layer due to BMA self-shading and extinction due to sediment solids:

$$I = I_s e^{-Ks*z} \qquad \text{(VII-5)}$$

where:
Is = irradiance at surface of BMA layer (same as irradiance at bottom of water column)
Ks = light attenuation within BMA layer due to BMA self-shading and sediment (m^{-1})
z = local coordinate measured down from surface of algal layer

Self-shading has been cited as an important factor influencing BMA (Cahoon and Cooke, 1992). Consequently, it is reasonable to separate K_s (light attenuation) into two terms; one is self-shading related to the BMA biomass, and the other is sediment solids extinction. The mean light within the BMA layer is represented as:

$$I_{mean} = I_o e^{-Ksed} \frac{1 - e^{-Kalgae*B}}{Kalgae*B} \qquad \text{(VII-6)}$$

where:
I_{mean} = available light within BMA layer
Io = irradiance at the surface of sediment
K_{sed} = attenuation due to sediment solid
K_{algae} = attenuation due to benthic microalgae self-shading ($m^2 g^{-1} C$)
B = benthic microalgae biomass (g C m^{-2})

Equation (VII-6) mainly constrains unlimited growth of BMA. When the biomass of BMA becomes larger, the mean light within the BMA layer will be smaller. As a result, BMA growth will be limited. Irradiance at the surface of the BMA layer is calculated from the irradiance at the surface of the water column through the following equation:

$$\mathrm{Ke} = \mathrm{a}_1 + \mathrm{a}_2 * TSS + \mathrm{a}_3 * CHL \qquad \text{(VII-7)}$$

where:

a_1 = background attenuation (m^{-1})
a_2 = attenuation by inorganic suspended solids (m^2 g^{-1})
a_3 = attenuation by organic suspended solids (m^2 gm^{-1} CHL)
TSS = total suspended solids concentration (g m^{-3})
CHL = chlorophyll-a concentration (mg CHL m^{-3})

Nutrients

The influence of nutrients on BMA production is represented by the Monod formulation:

$$f(N) = \frac{N}{Kh + N} \qquad \text{(VII-8)}$$

where:
N = concentration of nutrient available for BMA uptake (g m m^{-2})
Kh = nutrient concentration at which algal uptake is halved (g m m^{-2})

There are two nutrient sources for BMA, one from the water column and the other from returned nutrients as they diffuse from the sediment into the overlying water column. A nutrient concentration available on an areal basis is calculated as follows:

$$N = Nflux * \Delta t + Nwater * Hwater \qquad \text{(VII-9)}$$

where:
N*flux* = sediment nutrient release (g m^{-2} d^{-1})
Δt = discrete time step (day)
N*water* = nutrient concentration in overlying water (g m^{-2})
H*water* = depth of bottom layer (m)

Two nutrients potentially limit BMA production: dissolved inorganic nitrogen and phosphorus. As in the case for phytoplankton, Liebig's "law of the minimum" (Odum, 1971) is used. Therefore, nutrient limitation is determined by the most limiting nutrient. Based on the reported value, half-saturation constants were set as K_{hn} = 0.01 g N m^{-2} for nitrogen and K_{hp} = 0.001 g P m^{-2} for phosphorus (Cerco and Seitzinger, 1997). It is assumed that silica is not a limiting factor in the present BMA model, even though benthic diatoms can uptake silica.

Temperature

Temperature is also shown to have a strong effect on production, respiration, and grazing rates. For example, temperature was recognized to account for up to 70% of the variability of microphytobenthic populations (Uthicke and Klumpp, 1998). The effect of temperature on algal production is represented by a function similar to a Gaussian probability curve:

$$\begin{aligned} f(T) &= \exp\left(-KTG1\,[T - TM]^2\right) \quad \text{when } T \leq TM \\ &= \exp\left(-KTG2\,[TM - T]^2\right) \quad \text{when } T > TM \end{aligned} \qquad \text{(VII-10)}$$

where:
TM = optimal temperature for BMA growth (°C)
KTG1 = effect of temperature below TM on BMA growth ($°C^{-2}$)
KTG2 = effect of temperature above TM on BMA growth ($°C^{-2}$)

As a result, BMA production increases as a function of temperature until an optimum temperature is attained, and then decreases with temperature after an optimum temperature is reached.

Basal metabolism (Respiration)

Basal metabolism is commonly considered to be an exponentially increasing function of temperature:

$$BM = BMR * \exp[KTB\,(T - TR)] \qquad \text{(VII-11)}$$

where:
BMR = metabolic rate at reference temperature TR (day $^{-1}$)
KTB = effect of temperature on metabolism ($C^{\circ-1}$)
TR = reference temperature for metabolism (C°)

Predation

Predation is calculated by a relationship identical to that for respiration:

$$PR = BPR * \exp\,[KTB\,(T - TR)] \qquad \text{(VII-12)}$$

where:
BPR = predation rate at TR (day $^{-1}$)
KTB = effect of temperature on predation ($C^{\circ-1}$)
TR = reference temperature for predation (C°)

The rates of both metabolism and predation for BMA both increase with temperature. The differences lie in the parameter values, and their distribution.

VII-2 Nutrient Budgets in the Lynnhaven River

A nutrient budget provides a basis for assessing potential effects of system responses in the context of various sources and sinks. The purposes for constructing the nutrient budget were: (1) to present the nutrient pathway on an annual basis, especially under the scenarios of with and without the effects from BMA, (2) to evaluate the relative importance of the various sources and sinks of nitrogen and phosphorus during the seasonal cycle from the monthly nutrient budget, (3) to estimate recycling processes in order to allow estimates of turnover times and the relative importance of "new" versus "recycled" nutrients, and (4) to quantify nutrient export to the coastal ocean and losses from the sediment on an annual basis comparing with results from deep water systems (Nixon et al., 1996).

In order to quantify the nutrient budget in an estuary, both nutrient storage in sediments and nutrient exchange with the ocean and the atmosphere must be quantified. Nutrient storage in sediments is difficult to measure in the field due to large spatial and temporal gradients (Boynton et al., 1995). Nutrient exchange with the outside ocean is complicated by tidal currents, with large temporal and spatial gradients (Kjerfve and Proehl, 1979). Therefore, the nutrient budget calculation from a well-calibrated numerical model represents one of the most efficient and accurate ways to achieve the goal.

VII-2-1 Annual nutrient budget in Lynnhaven River system

This Lynnhaven hydrodynamic/water quality model comprises the estimate of major inputs, exports, storages, and recycling of TN and TP in the Lynnhaven River proper and its branches. There are two types of nutrient inputs into the system including nonpoint loading from watershed and atmospheric sources. Loss terms include burial of TN and TP in sediments in depositional portions of study areas, denitrification of N in sediments, and net exchanges of N and P at the mouth of the river. Since it is probably a small source as is the case in most nutrient-rich estuarine systems, nitrogen fixation is not evaluated (Howarth et al., 1988).

The conceptual model of the nutrient budget can be expressed as differential equations for TN and TP both in the water column and in the sediment based on Boynton et al. (1995). In the water column, the time rates of change of TN and TP vary with nonpoint, atmospheric and depositional fluxes, and oceanic sources:

$$\frac{dTN_w}{dt} = TN_{nonpoint} + TN_{atm} - TN_{dp} + TN_{flux} + TN_{ocean} \quad \text{(VII-13)}$$

$$\frac{dTP_w}{dt} = TP_{nonpoint} + TP_{atm} - TN_{dp} + TN_{flux} + TN_{ocean} \quad \text{(VII-14)}$$

In the sediment, the important processes impacting the time rates of changes of TN and TP include deposition, flux, burial, and denitrification:

$$\frac{dTN_s}{dt} = TN_{dp} - TN_{flux} - TN_{burial} - TN_{denitri} \qquad \text{(VII-15)}$$

$$\frac{dTP_s}{dt} = TP_{dp} - TP_{flux} - TP_{burial} \qquad \text{(VII-16)}$$

where:

TN_w, TP_w	= total nitrogen, phosphorus in water column
TN_s, TP_s	= total nitrogen, phosphorus in sediment
$TN_{nonpoint}$, $TP_{nonpoint}$	= total nitrogen, phosphorus loading from nonpoint source
TN_{atm}, TP_{atm}	= total nitrogen, phosphorus loading from atmosphere
TN_{dp}, TP_{dp}	= total nitrogen, phosphorus deposition into sediment
TN_{flux}, Tp_{flux}	= total nitrogen, phosphorus flux from sediment into water column
TN_{ocean}, TP_{ocean}	= net total nitrogen, phosphorus exchange with adjacent seaward system
TN_{burial}, TP_{burial}	= total nitrogen, phosphorus burial in deep sediment
$TN_{denitri}$	= total nitrogen, phosphorus denitrified in sediment

Annual nutrient budget in the mainstem of Lynnhaven River

The mean annual water quality budget in the Lynnhaven River was studied first. It was assumed that, on an annual basis, the nutrient species are in an equilibrium condition. Consequently, $\frac{dTN_w}{dt}$, $\frac{dTP_w}{dt}$, $\frac{dTN_s}{dt}$ and $\frac{dTP_s}{dt}$ are equal to zero by definition. The results of annual nutrient budgets are shown in Figure VII.2 and Figure VII.3 (values in parentheses denote results without BMA).

Annual TN and TP budgets, reported in units per square meter of surface area of Lynnhaven River, show the loading of nutrients from the watershed we calculated is slightly less than that for Chesapeake Bay (Boynton et al., 1995). Our loading for Lynnhaven River is 27.79 (mg N m^{-2} d^{-1}) for TN and 2.08 (mg P m^{-2} d^{-1}) for TP. In a previous comparison with Chesapeake Bay loading of nutrients from its watershed, TN loading was 36.01 (mg N m^{-2} d^{-1}) and TP loading was 2.67 (mg P m^{-2} d^{-1}). The ratio of the Lynnhaven River watershed (166 km^2) to the surface area of the receiving waters (18.1 km^2) is 9.2. This ratio for Chesapeake Bay is 14.4 (165,760 km^2 watershed area, 11,542 km^2 surface area of its receiving waters). The atmosphere deposition directly deposited through the surface of the river contributed only 9.5% for TN and 4.4% for TP. While direct atmospheric deposition represents a very small nutrient source compared to nonpoint sources from the watershed, the influence of atmospheric deposition on primary production may be larger. The reason for this is that a substantial fraction of TN and TP entering from watershed sources is in a form not directly available to phytoplankton, being either dissolved organic nutrient or a form of particulate material. However, virtually all of the nitrogen and phosphorus deposited from the atmosphere is immediately available for phytoplanktonic uptake.

Figure VII.2 and Figure VII.3 show the results of the water quality model simulation and indicate that, over lengthy time scales, benthic algae can influence most terms of the nutrient budget in the water column. The presence of BMA reduced the export of nutrients into Chesapeake Bay. There are two reasons: 1) a larger quantity of particulate nitrogen and phosphorus deposit into the sediment in the presence of BMA and 2) for nitrogen flux between the water column and sediment with BMA, the flux direction changed from traditional flux in that the BMA uptake dissolved nutrients both from the sediment and the water column, which causes the net dissolved nitrogen flux to occur from the water column into the sediment. For phosphorus flux between the water column and the sediment with BMA, the flux direction does not change, but less dissolved phosphorus is released from the sediment due to BMA uptake. The nutrients that are uptaken by BMA are stored in the sediment in winter and spring, and released from the sediment as dissolved nutrient in summer and autumn. Simulations indicate that larger quantities of dissolved nitrogen are incorporated into the sediments in the presence of benthic algae. Deposition of particulate nitrogen computed in the presence of benthic algae also increases. Enhanced deposition results from the stimulation of primary production in the water column by summer nutrients released in the presence of benthic algae.

The computed net annual flux of dissolved phosphorus is from the sediments to the water column, both with and without the effects of benthic algae (Figure VII.3). Annual average sediment release is diminished when algae are present, however, due to uptake during periods of benthic production. The simulation indicates that Lynnhaven River would export more phosphorus to the ocean in the absence of benthic algae.

Figure VII.2 and Figure VII.3 also indicate that benthic algae can influence burial and denitrification in sediment. For both particulate nitrogen and particulate phosphorus, computed deposition and burial is increased in the presence of benthic algae. As a result of the uptake by BMA and enhanced deposition, more nitrogen and phosphorus are buried into deep, unavailable sediments instead of being exported into Chesapeake Bay without benthic algae. The denitrification rate also increased due to BMA. In general, the annual averaged denitrification rates with BMA and without BMA are within the range 5 to 250 μmol N m^{-2} h^{-1} (1.68 mg N m^{-2} d^{-1} to 84 mg N m^{-2} d^{-1}) reported for several estuarine systems (Andersen et al., 1984; Seitzinger, 1988; 1990; Rysgaard et al., 1993; 1995; Nowicki et al., 1997; Sundbäck et al., 2000). The highest denitrification rate, 98 mg N m^{-2} d^{-1}, occurred in the late summer during the simulation including BMA. There are also several studies that show extremely high denitrification rates of approximately 500 to 1300 μmol N m^{-2} h^{-1} (168 to 437 mg N m^{-2} d^{-1}) in some estuarine sediments (Seitzinger, 1988; 1990; Ogilvie et al., 1997; Dong et al., 2000).

<u>Annual nutrient budget in the three tributaries of Lynnhaven River</u>

In the Lynnhaven River, there are three major branches: Western Branch, Eastern Branch, and Broad Bay. Their dynamics are different. It is valuable to characterize the difference between these three branches. For example, which tributary receives the majority of the nutrient loading from the watershed? Which tributary exports the largest quantities of nutrients into Chesapeake Bay? Using the same methodology described earlier, nutrient budgets in the three branches of Lynnhaven River were calculated (Figure VII.4 and Figure VII.5).

The results show that the Western and Eastern Branches receive significantly more nutrients than does Broad Bay. While the combined surface areas of the Western and Eastern Branches (11.1 km^2) comprise only 61% of the entire system (18.1 km^2), the percentage for nutrient loadings are 85% for TN and 83% for TP contributed from the watershed. The largest areal loadings of TN and TP are in Western Branch, which are almost 5 times and 4 times those in Broad Bay for TN and TP, respectively.

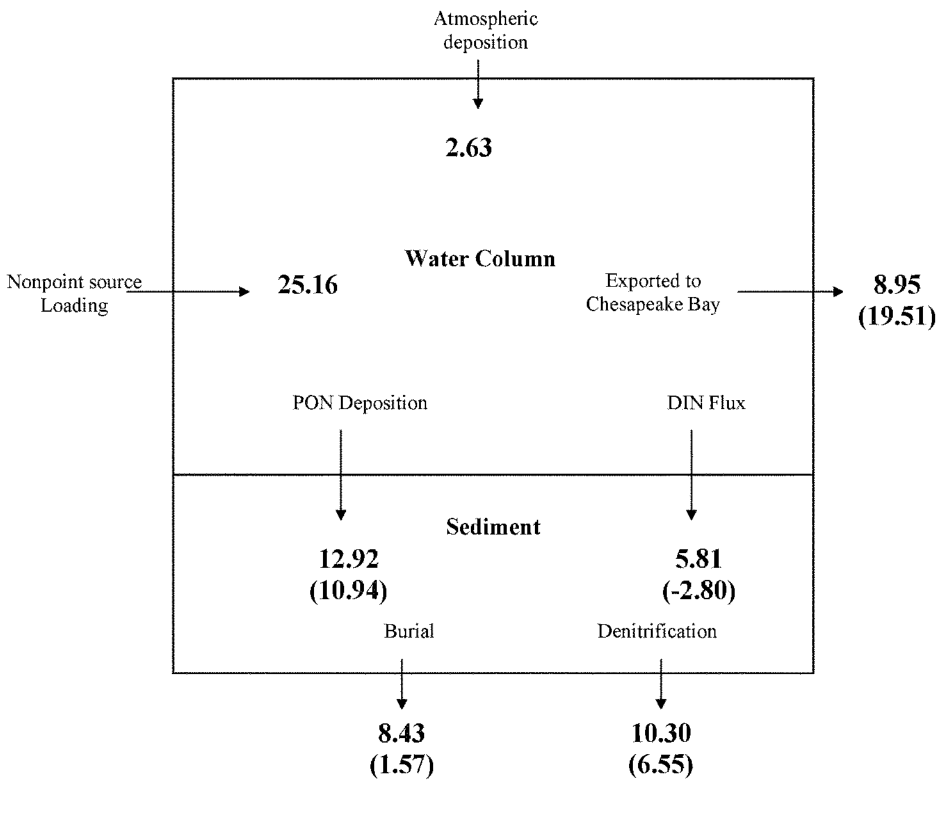


Figure VII.2. Annual Total Nitrogen budget (mg N m^{-2} d^{-1}) for Lynnhaven River (Values in parentheses indicate results without BMA)

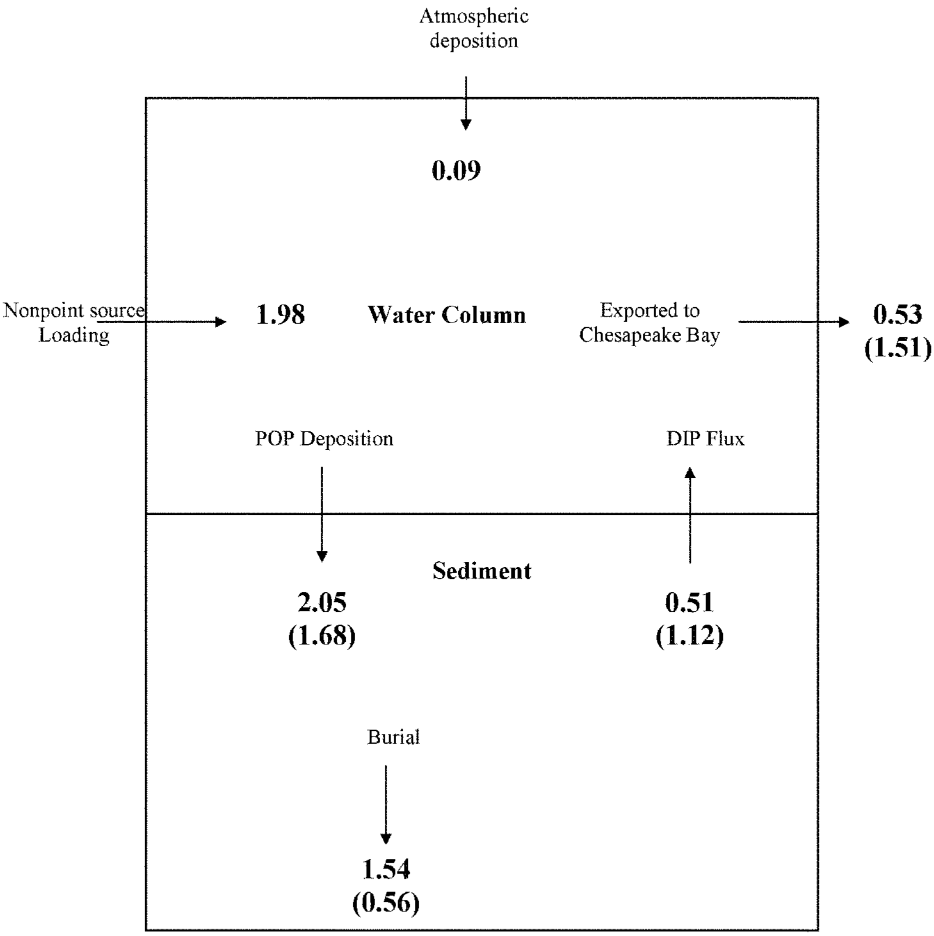


Figure VII.3. Annual Total Phosphorus budget (mg P m^{-2} d^{-1}) for Lynnhaven River (Values in parentheses indicate results without BMA)

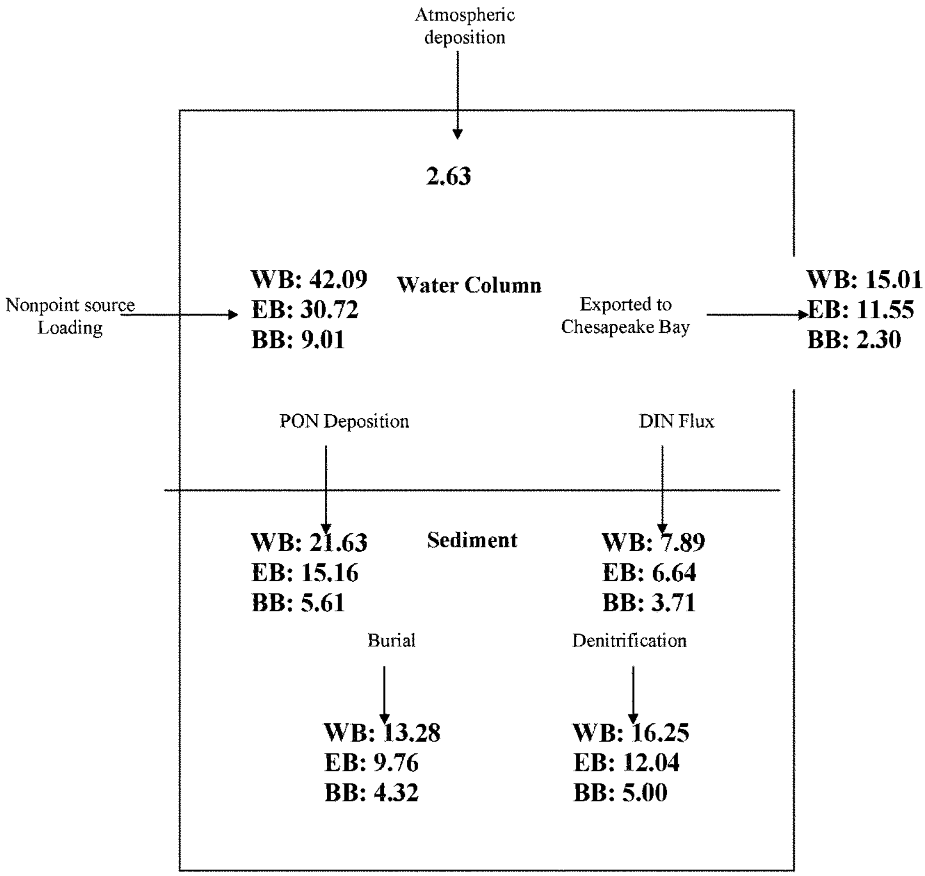


Figure VII.4. Annual Total Nitrogen budget (mg N m^{-2} d^{-1}) in three branches of Lynnhaven River (WB: Western Branch, EB: Eastern Branch, BB: Broad Bay)

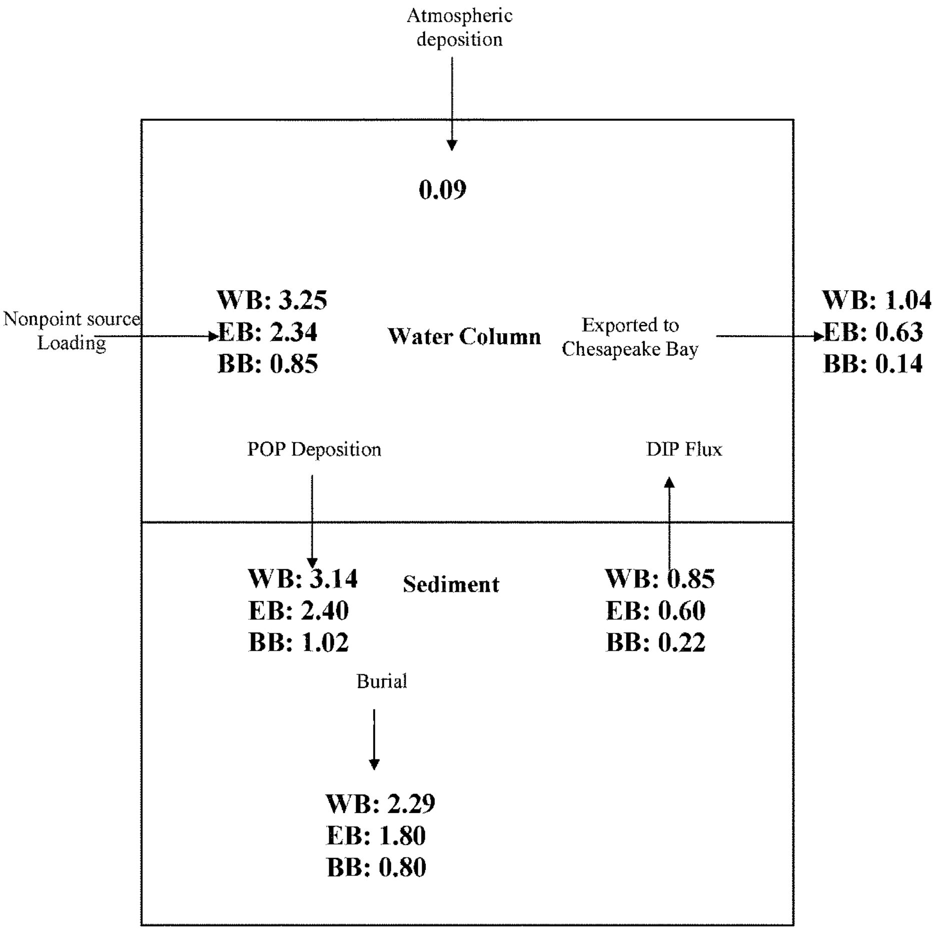


Figure VII.5. Annual Total Phosphorus budget (mg P m^{-2} d^{-1}) in three branches of Lynnhaven River (WB: Western Branch, EB: Eastern Branch, BB: Broad Bay)

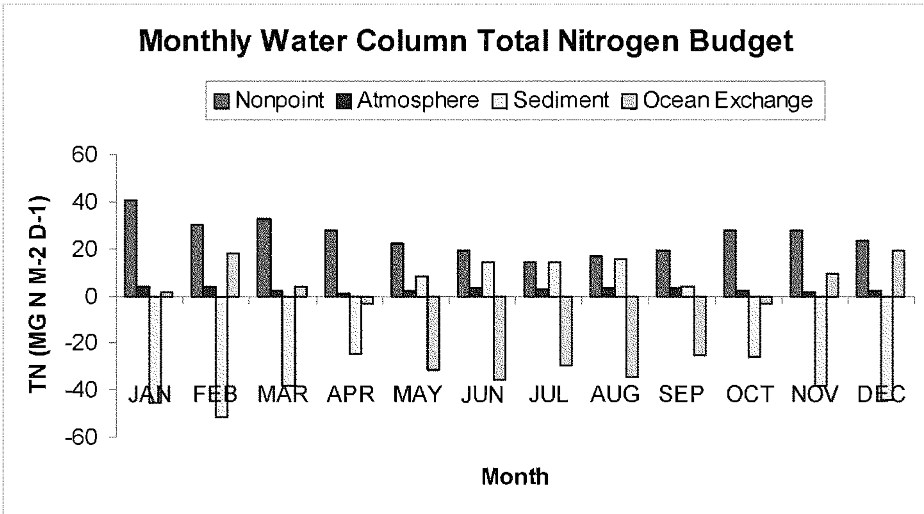
It is not surprising that most nutrients exported from the Lynnhaven into Chesapeake Bay are from the Western and Eastern Branches. With larger nutrient loadings, the Western and Eastern Branches contribute approximately 90% of TN and 89% of TP exported into Chesapeake Bay. The removal of nutrients via ocean exchange, as a percentage of TN input to the estuary, also varies between the three branches. The Western Branch exports 34% of its TN loading and 31% of its TP loading, the Eastern Branch exports 35% of its TN loading and 29% of its TP loading, and Broad Bay only exports 20% of its TN loading and 15% of its TP loading.

The difference appears to be due to different residence times for the three branches. From the results of an "age-of-water" investigation, we know that the residence time of either the Western or Eastern Branch is approximately 12 days for the mean flow condition, which is much smaller than that of Broad Bay, 72 days. Nixon (1996) showed that the net transport of nutrients through a system to the outside ocean is inversely correlated with the residence time of water in the system. With larger nutrient loading, the Western and Eastern Branches also show larger values of particulate nutrient deposition, dissolved nutrient flux, final burial into deep sediment, and denitrification rates than these values for Broad Bay.

VII-2-2 The monthly nutrient budget for the Lynnhaven River system

There are other time scales, such as seasonal time scales, that are important for the nutrient budget. The monthly nutrient budget was calculated using the formula presented above. For the water column, the monthly budget for the entire year is shown in Figure VII.6. It indicates that nonpoint sources account for most external loadings of nitrogen and phosphorus to the Lynnhaven River through the entire year. Atmospheric nitrogen and phosphorus loadings are almost constant throughout the year. From October through April, the sediment is the major sink of nitrogen from the water column. From May to September, sediments release remineralized nitrogen to the water column and function as a source. During July and August, sediment-released nitrogen is larger than the nonpoint source loading. From November through March, Lynnhaven River exports nitrogen to the Chesapeake Bay. During the rest of the year, nitrogen imports from the ocean are substantial. The monthly budget for phosphorus also reveals a similar pattern. From October through March, the sediment is the major sink. From April to September, sediments act as a source by releasing phosphorus to the water column. From October through February, the Lynnhaven River exports phosphorus to the Chesapeake Bay. Similar monthly patterns of the nutrient budget were found by Cerco and Seitzinger (1997) for their analysis of the Indian River-Rehoboth Bay system.

The sediment nutrient budget was also calculated (Figure VII.7). During winter and spring, sediments are net sinks of nutrients from the water column. Settling of nutrients in particulate form is one component of the nutrient budget during these months. In addition, BMA also uptake dissolved inorganic nutrients. Benthic fluxes of total dissolved nutrients are dominated by uptakes throughout the spring and winter. Benthic microalgae can assimilate a large proportion of the nitrogen and phosphorus and produce oxygen in the sediments (Ferguson et al., 2004).



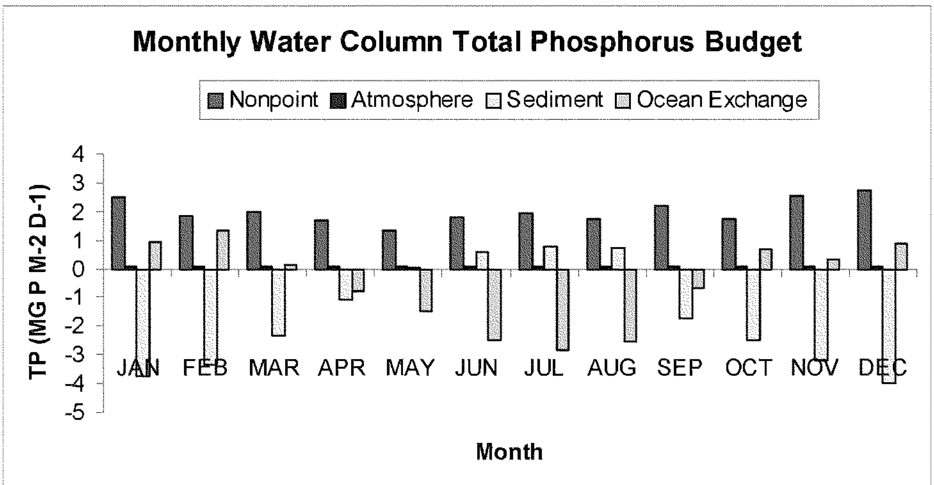
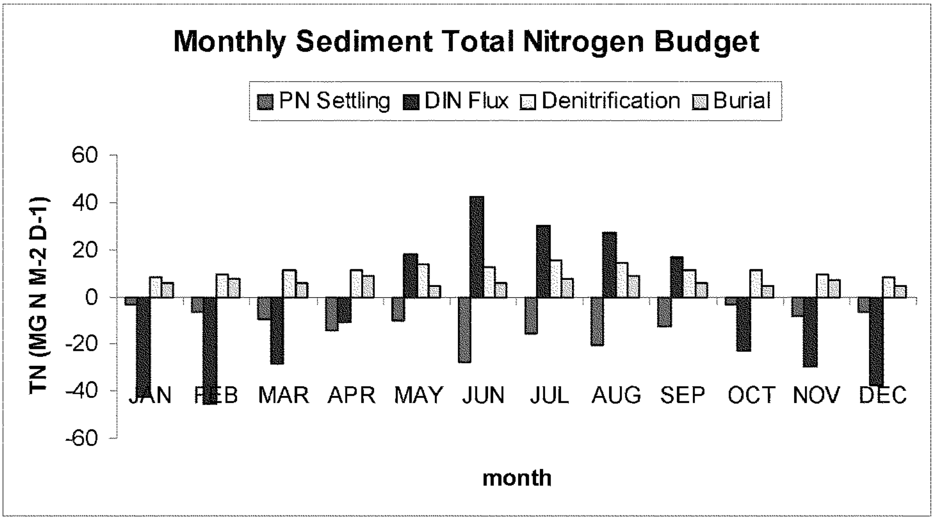


Figure VII.6. Monthly Total Nitrogen budget (mg N m^{-2} d^{-1}) and Total Phosphorus budget (mg P m^{-2} d^{-1}) in the water column for Lynnhaven River (positive means entering the water column, and negative means leaving the water column)



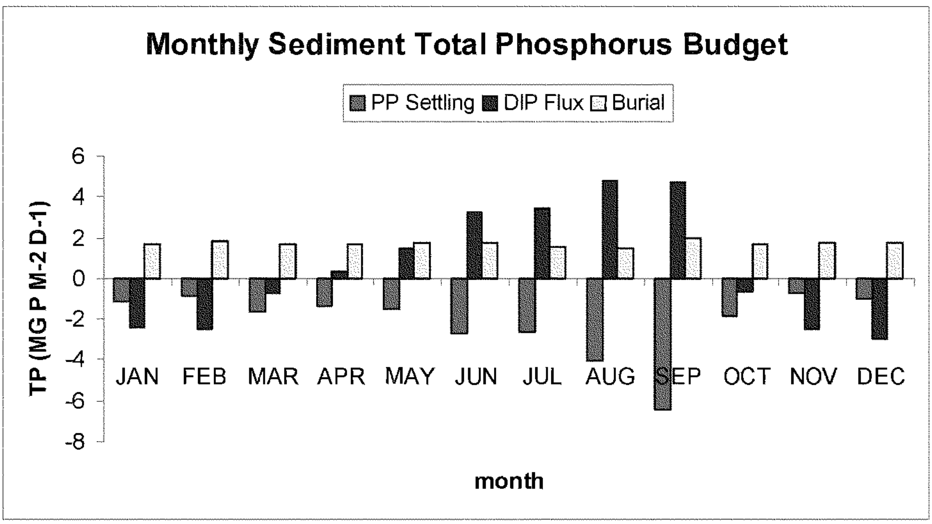


Figure VII.7. Monthly Total Nitrogen budget (mg N m^{-2} d^{-1}) and Total Phosphorus budget (mg P m^{-2} d^{-1}) in sediment for Lynnhaven River (positive values indicate leaving sediment, negative values indicate entering sediment)

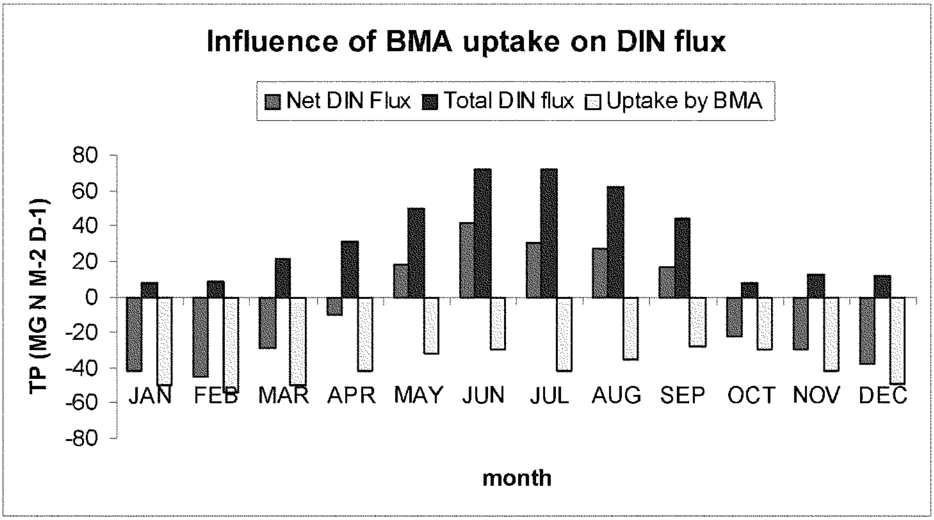
In April or May, the system undergoes a change as the sediment begins to release nutrients. It is possible that, in this condition, the extra pelagic production and resulting light extinction would decrease BMA production, leaving an unsustainable benthic respiratory requirement. Meanwhile, phytoplankton assimilate dissolved nutrients in the water column, which lowers the concentration of dissolved nutrients. The coupled effects cause sediments to release dissolved nutrients into the water column. Cerco and Seitzinger (1997) also indicated that this change is caused by phytoplankton shading out benthic algae and primary production in the water column exceeding production in the sediments. When temperatures become relatively high during this period, phytoplankton in the water column receive more light than BMA in the sediment. Mineralization of the organic matter in the sediments also increases with high temperature in summer, and dissolved inorganic nutrients are released from the sediment and support the primary production in the water column. Phytoplankton growth exceeds BMA, since light available to BMA decreases due to shading by phytoplankton. In summer and autumn, the sediments are a net source of nutrients to the water column.

In order to illustrate the influence of BMA uptake on sediment dissolved nutrient flux, Figure VII.8 shows the monthly dissolved nitrogen and phosphorus assimilated by BMA with the total and net nutrient fluxes. The total nutrient flux, without BMA uptake, indicates that sediment released both nitrogen and phosphorus over the entire year. The most intense period of release of nutrients from the sediment occurred in summer. The dissolved nutrients assimilated by BMA exceeded the released nutrients in winter and spring, while the released nutrients from the sediment dominated in summer and autumn. In summary, BMA could reverse the direction of nutrient sediment flux in early spring and late autumn.

VII-3 Comparison of Nutrient Budget between Shallow and Deep Water Systems

In deep estuaries, sediment-regenerated nutrients often account for the majority of the total nutrients regenerated. For example, the annual sediment releases of nitrogen and phosphorus ranged from 55% to 233% and 44% to 2140%, respectively, of their annual terrestrial plus atmospheric inputs. The most intense sediment nutrient flux from the sediment into the water column occurred in summer. In Lynnhaven River, however, the annual sediment flux of nitrogen is from the water column into the sediment. From monthly budget results, it is clear that the sediment still releases nitrogen in summer and fall as in deep estuaries, but the BMA in the sediment uptake nitrogen from the water column in winter and spring. The overall effect of annual sediment nitrogen flux is from the water column into the sediment. Meanwhile, the uptake effect of BMA also reduces the magnitude of the phosphorus flux from the sediment into the water column.

In most estuaries, nutrient loadings are dominated by freshwater inputs during spring. With abundant nutrients in the water column, phytoplankton usually bloom in spring, for example, in Chesapeake Bay (Kemp and Boynton, 1984; Malone et al., 1988). After phytoplankton decay and sink into the sediment, the recycling of nutrients from the sediments then supports further phytoplankton productivity in the summer (Kemp and Boynton, 1984; Rysgaard et al., 1995). It appears that nutrient cycling in these systems



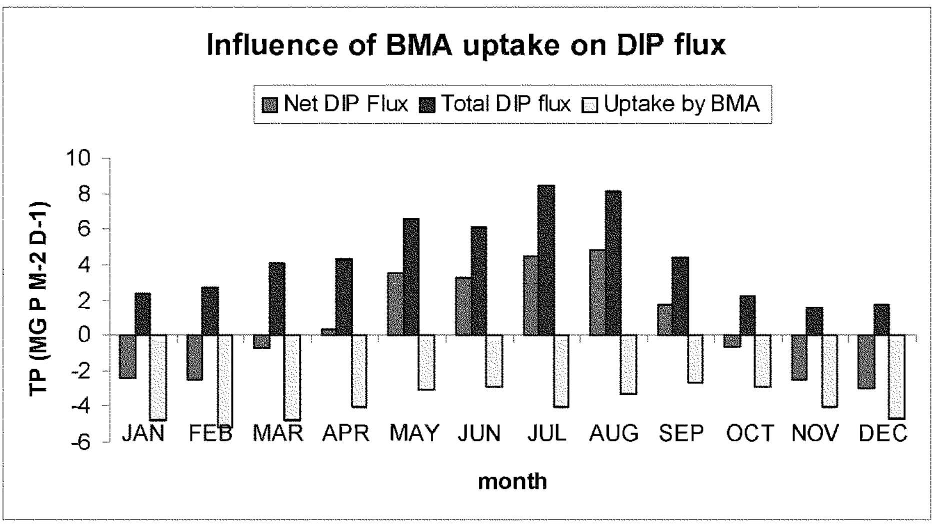


Figure VII.8. Monthly BMA uptake contribution to sediment flux nitrogen and phosphorus for Lynnhaven River (Positive values indicate leaving sediment, negative values indicate entering sediment) occurs over reasonably broad, seasonal time scales. In Chesapeake Bay, nutrients are removed from the water column during the spring phytoplankton bloom and are subsequently deposited in the sediments as detritus. A spring phytoplankton bloom has not been observed in the Lynnhaven River. However, the benthic algal bloom plays the role of the phytoplankton bloom in the deeper system. After BMA assimilates nutrients in winter and spring, nutrients stored in particulate form enter into the sediment. The microbial processes are responsible for nutrient regeneration in sediments, which are sensitive to temperature and oxygen conditions. In summer, nutrients are released from the sediment and support the water column primary production. Overall, mineralization of the organic matter stored in the sediments by BMA supports the summer maximum in the annual primary production.

Nixon et al. (1996) showed that the net transport of nutrients through estuaries to the continental shelf is inversely correlated with residence time of water in the system. Without BMA, the annual nutrient budget indicates that 70% of TN and 73% of TP, respectively, entering from land and atmosphere would be exported into Chesapeake Bay. These estimations of the efficiency of nitrogen and phosphorus transports through the Lynnhaven River fit well with the findings of Nixon et al. (1996), assuming that the residence time of water in the Lynnhaven River is 35 days (Figure VII.9). With the BMA, however, only 32% of TN and 26% of TP entering would be exported into Chesapeake Bay. This indicates that, as nutrients transported through the Lynnhaven River, more nutrients could be removed from the water column due to BMA uptake and subsequently through the buried and denitrified in sediments. This provides an alternative mechanism for the nutrient pathway in the shallow water system.

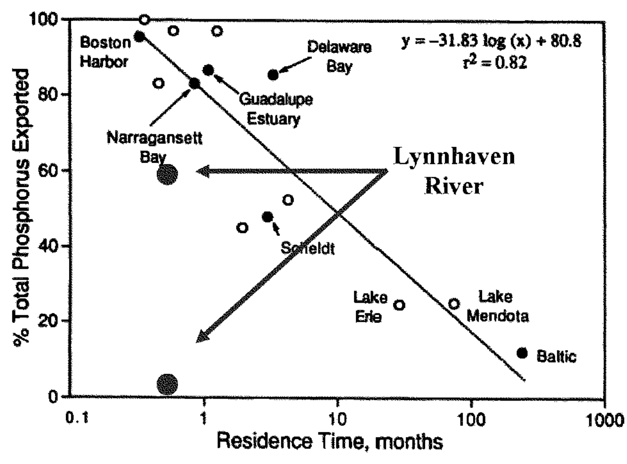


Figure VII.9. The percent of total nitrogen and phosphorus input from land and atmosphere that is exported from a sample of estuaries and lakes as a function of mean residence time in the system. Estuarine data marked as solid points; lake data marked as open circles (Nixon et al., 1996; modified); regression equations calculated by Nixon et al. (1996) (Blue dot shows results without BMA; red dot shows results with BMA)

CHAPTER VIII. DISCUSSION AND CONCLUSIONS

The Virginia Institute of Marine Science (VIMS) has successfully developed an integrated numerical modeling framework for the Lynnhaven system, a shallow water coastal bay in the City of Virginia Beach, Virginia. This framework combines a high-resolution 3D hydrodynamic model (UnTRIM) that provides the required transport for a water quality model (CE-QUAL-ICM) that, in turn, provides intra-tidal predictions of 23 water quality state variables. A suspended sediment transport model was also developed and incorporated into the modeling framework.

The hydrodynamic model UnTRIM is a state-of-the-art numerical model using an un-structured grid, which is able to follow complex shoreline geometry more closely than the traditional structured grid. This feature is particularly important for application to a shallow water body like the Lynnhaven system. The percent error in water volume due to any inaccuracy of the fitting of the model grid to the shoreline is amplified when the relative volume of deeper water decreases with decreasing overall depth. The UnTRIM model employs an Eulerian-Lagrangian approach and a semi-implicit numerical scheme to solve the momentum equation, thus eliminating the constraint of Courant's condition and allowing a much larger time step (of the order of 10 minutes) in numerical computation. This is advantageous over the hydrodynamic model using the Eulerian approach, since the model needs to run for an extended period, normally longer than the annual cycle, to supply transport to the water quality model for evaluating seasonal variations in water quality conditions. The selection of CE-QUAL-ICM was based on its history of application to the Chesapeake Bay system. However, it was later deemed necessary to modify it by including the benthic microalgae for the application to the Lynnhaven system.

Prior to the inception of the model development, all available historical Lynnhaven hydrodynamic and water quality data were amassed in a MicroSoft ACCESS database and analyzed for model calibration suitability and long-term trends. These data were collected from monitoring programs of the Virginia Department of Environmental Quality (VA-DEQ) and the Virginia Health Department, Shellfish Sanitation Division (VA-DSS), intensive surveys conducted by VIMS and Malcolm Pirnie Environmental Engineers, and tidal surveys conducted by the National Oceanic and Atmospheric Administration (NOAA).

A strategy of project-specific field surveys and laboratory experiments was devised based on which measurements would complement the existing historical data and be most useful to the model calibration and validation processes. These field surveys and experiments included the following:

- a hydrodynamic survey of synoptic measurements of times series of surface elevations plus currents and salinities in all Lynnhaven branches and outside the Inlet

- seasonal sediment flux measurements at the Inlet and in all branches to determine the spatial and seasonal variations of the fluxes from the water column to the sediment (and vice versa) of dissolved oxygen, ammonia, nitrate-nitrite, and phosphate

- sediment flux measurements of dissolved oxygen, ammonia, nitrate-nitrite and phosphate in the laboratory under controlled environments

- critical shear stress measurements at multiple sites in the basin to determine the spatial and seasonal variations to the erodibility of bottom sediments

- high-frequency time series measurements of chlorophyll-a, turbidity, Colored Dissolved Organic Matter (CDOM), and dissolved oxygen (DO) to evaluate water quality conditions with high temporal resolution

The analyses of sediment flux data of laboratory experiments clearly have indicated that benthic microalgae (BMA) play a significant role in the pelagic-benthic exchange process in the Lynnhaven system. The importance of the BMA process in shallow waters has been documented by other studies in various water bodies. Therefore, a microalgae model was developed based on the experimental data and literature formulations, and incorporated into the water quality model CE-QUAL-ICM. The BMA growth can reduce the rates, or even reverse the directions, of nutrient and oxygen exchanges between the water column and sediment, and significantly affect the nutrient budget of a water body. The photosynthesis of BMA would assimilate nutrients from the water column, store them in the sediment, and further bury them into deep sediment, or nitrify them in the case of nitrogen. Therefore, fewer nutrients would be exported out of the system. The VIMS model study indicated that 32% of total nitrogen and 26% of total phosphorus inputs into the Lynnhaven system were exported to the Chesapeake Bay.

The hydrodynamic portion of the integrated model was calibrated using historical datasets and NOAA tide predictions. The water quality portion of the model was calibrated using the 2006 data set collected by the VA-DEQ. The calibration parameters were adjusted, within their literature ranges, to achieve the best agreement between the model predictions and observation data.

Validation of the hydrodynamic model was made by comparing the 2005 simulation results with observations collected in VIMS hydrodynamic surveys of that year. Validation of the water quality model was conducted with a two-year model run simulating the water quality conditions of 2004-2005. The model predictions were compared with the monitoring data of VA-DEQ. Satisfactory agreements between the model predictions and field observations were achieved without altering any values of calibration parameters that were set in the calibration process.

The sediment transport model was developed utilizing the equilibrium critical shear stress defined at the interface between layers, and incorporated into the modeling framework. The values of some model parameters were derived from the critical shear stress measurements conducted specifically for the project, and the others were from literature reports. This model was calibrated by comparing its predictions of total suspended solids (TSS) with observations at the 16 Lynnhaven VA-DEQ stations during 2006 and validated by comparing the 2004-2005 model results with VA-DEQ observations for those years. Additionally, the validation compared model predictions with TSS values derived from VIMS high-frequency measurements of turbidity at 3 locations in 2005.

The model sensitivity analyses showed that 70% of total nitrogen and 73% of total phosphorus would have been exported if there were no BMA growth in the system. The CE-QUAL-ICM could not have successfully simulated the water quality conditions in the Lynnhaven system without the modification of including BMA. The BMA model developed by VIMS accurately predicted the oxygen and nutrient water-sediment flux measurements in the laboratory for various seasons and different locations. The addition of BMA model enabled the CE-QUAL-ICM to successfully simulate the water quality conditions in the Lynnhaven system.

There are two water quality problems identified through data analyses and model simulations. One is the degraded water clarity due to significant concentrations of suspended sediment. The other is the localized summertime low dissolved oxygen in headland areas. The modeling framework developed by VIMS is ready for its application in conducting scenario runs. The model should be used as a management tool to assess the effectiveness of alternative managing practices to mitigate these problems.

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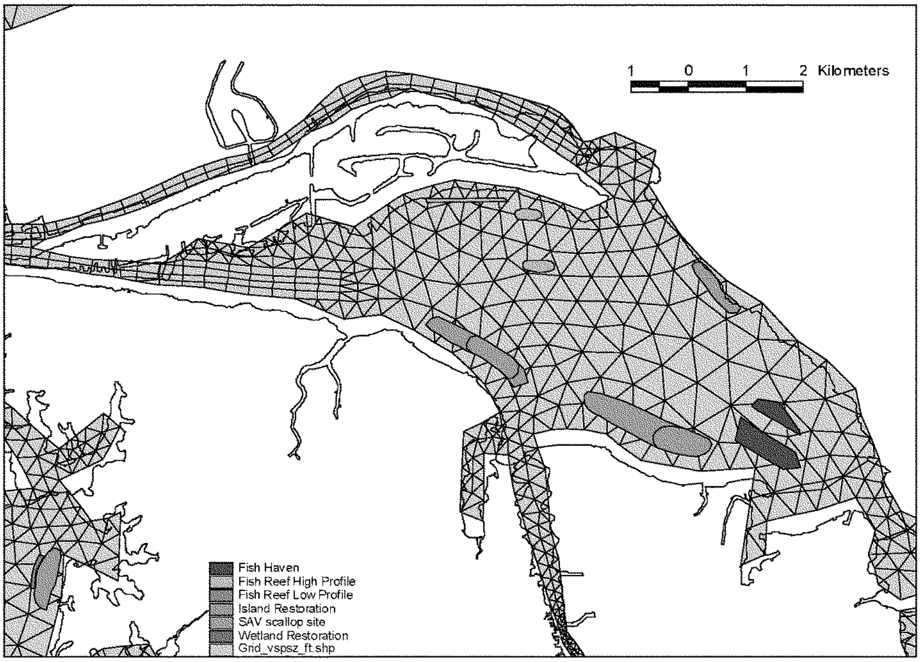
APPENDIX A

ATTACHMENT 2

NUMERICAL MODELING SCENARIO RUNS TO ASSESS TSS AND CHLOROPHYLL REDUCTIONS CAUSED BY ECOSYSTEM RESTORATION, LYNNHAVEN RIVER

Numerical Modeling Scenario Runs to Assess TSS and Chlorophyll Reductions Caused by Ecosystem Restoration, Lynnhaven River



Mac Sisson, Yuepeng Li, Harry Wang, and Albert Kuo

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I. Background and Introduction

The Lynnhaven River System, comprised of the Eastern and Western Branches, Long Creek, Broad Bay, and Linkhorn Bay, is located in Virginia Beach, Virginia, on the south shore of the Chesapeake Bay. It flows northerly and empties into the Chesapeake Bay about 10 miles east of Norfolk. Due to its narrow entrance and greater influence by the tide of the Bay than by river discharge, it is technically considered as a tidal inlet system. The watershed of the Lynnhaven River system is approximately 50 square miles in southeastern Virginia. The Lynnhaven River system was once a highly productive ecosystem, supporting a large oyster population and various shallow water organisms.

Like many Chesapeake Bay small coastal basins, however, the water quality conditions in Lynnhaven River system have deteriorated. A Reconnaissance Report issued by the U. S. Army Corps of Engineers (2002), cited a number of problems in water quality deterioration, siltation, sedimentation, and habitat management in the Lynnhaven. In 2005, the Army Corps of Engineers, along with the City of Virginia Beach, commissioned the Virginia Institute of Marine Science (VIMS) to develop a comprehensive three-dimensional hydrodynamics and water quality modeling capability for the Lynnhaven River System.

During that project, entitled "Development of 3D hydrodynamic and water quality models in the Lynnhaven River System", VIMS personnel developed an unstructured grid serving as the platform for executing its hydrodynamic model UnTRIM in the Lynnhaven. The modeling domain exterior boundary was selected with the intent to cover all significant receiving waters of the Lynnhaven (i.e., Western Branch, Eastern Branch, and Broad Bay and Linkhorn Bay). The model domain, along with the locations of DEQ stations at which the UnTRIM hydrodynamic and CE-QUAL-ICM water quality models were calibrated and validated, is shown in Figure 1.

The development of these models has provided the Corps and the City of Virginia Beach with a means of quantifying measures (e.g., nutrient load reductions) needed for the restoration of the system. It has also helped those involved with the restoration to identify and address the most troubling water quality "*hot spots*" of the system, such as Mill Dam Creek – Dey Cove and Thalia Creek – Thurston Branch.

Over this same period, the Army Corps has achieved a great deal of progress in its focus of restoring a viable critical mass of oyster reefs while implementing the most recent theories of successful reef construction. The next question is: "will this success of oyster population restoration have a positive feedback effect on the water quality of the Lynnhaven?"

As part of the ecosystem restoration of the Lynnhaven, the Corps is proposing to develop structure-based restorations of the following items: oyster reefs, scallops, SAV, and wetlands at selected locations spanning all 3 branches of the Lynnhaven. The locations of these proposed restoration sites are shown in the map in Figure 2. On this figure, the habitat types are color-coded with essential fish habitats (EFHs) shown in blue, SAV/Scallop sites shown in orange, and wetland restoration sites shown in green.

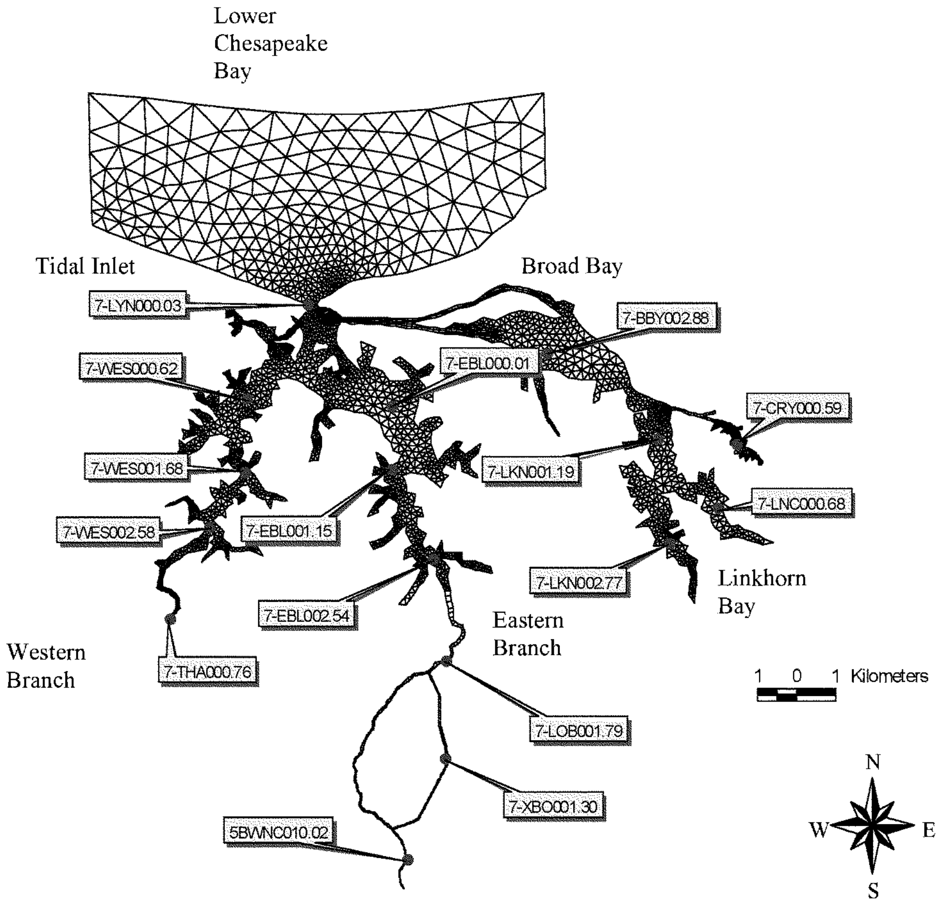

Figure 1. The unstructured grid for Lynnhaven River System and the locations of the 16 Lynnhaven stations monitored by the Virginia Department of Environmental Quality.

An important part of the restoration planning effort is to determine a metric for which the benefits of restoration site construction can be assessed. It is known that established restoration sites will remove total suspended solids (TSS) from the water column, including the volatilized portion of TSS (i.e., organic matters such as phytoplankton). Additionally, it can be shown that chlorophyll uptake rates at restoration sites are correlated with secondary productivity (Schulte, 2010). Given that the Army Corps of Engineers' plan for restoring SAV, scallops, and oyster reefs has a large potential to reduce total suspended solids (TSS) and chlorophyll levels, measurements of these reductions over the temporal and spatial scales that are present may not be feasible. In contrast, a calibrated model that has been properly formulated is capable of addressing "*what-if*" questions and quantifying the impact in a Lynnhaven basin-wide scale. This justifies the use of hydrodynamic and water quality models to perform the task if both the TSS reduction and the secondary production rates can be estimated (e.g., in units of kg/acre/month), and if the acreages and locations of each restoration habitat type are known, it is possible to incorporate these rates into the computations made by the hydrodynamic and water quality models. This may be done by adding sink terms into the UnTRIM hydrodynamic model that represent TSS removal and sink terms into the CE-QUAL-ICM water quality model that represent chlorophyll-a removal.

VIMS has worked with the Army Corps of Engineers to develop a methodology to assess the impact of proposed restoration plans, including SAV, scallops, and fish reefs (including oyster reefs) on the TSS and chlorophyll levels near these restoration sites.

II. Methodology

II-1. Modeling Phytoplankton Kinetics and TSS concentration

The kinetic equations for algae are:

$$\frac{\delta B_x}{\delta t} = (P_x - BM_x - PR_x)B_x - WS_x\frac{\delta B_x}{\delta z}$$

where:
B_x = algal biomass (g C m^{-3})
t = time
P_x, BM_x, PR_x = production, basal metabolism, and predation rates of algae, respectively (day^{-1})
z = the vertical coordinate and WS_x = algal settling velocity (m day^{-1}).
The subscript, **x**, is used to denote three algal groups: **f** for dinoflagellates, **d** for diatoms, and **g** for greens.

(a) Growth (Production)

Algal growth depends on nutrient availability, ambient light, and temperature. The effects of these processes are considered to be multiplicative as follows:

$$P_x = PM_x \cdot f(N) \cdot f(I) \cdot f(T)$$

where:
PM_x = maximum production rate under optimum conditions (day^{-1})
f(N), f(I), f(T) = effect of sub-optimal nutrient, light intensity, and temperature, respectively.

Effect of nutrients on growth

$$f(N) = \text{minimium}\left\{\frac{NH4 + NO3}{KHN_x + NH4 + NO3}, \frac{PO4d}{KHP_x + PO4d}, \frac{SAd}{KHS_d + SAd}\right\}$$

where:
NH4, NO3 = ammonium and nitrate nitrogen concentrations, respectively (g N m^{-3})
PO4d = dissolved phosphate concentration (g P m^{-3})
SAd = dissolved silica concentration (g Si m^{-3})
KHN_x = half-saturation constant for algal nitrogen uptake (g N m^{-3})
KHP_x = half-saturation constant for algal phosphorus uptake (g P m^{-3})
KHS_d = half-saturation constant for silica uptake by diatoms (g Si m^{-3})

Effects of light on growth

$$f(I) = \frac{1}{KESS \cdot \Delta z} \ln\left(\frac{IH_x + I_{TOP}}{IH_x + I_{BOT}}\right)$$

Where:

$$I_{TOP} = I_{SFC}\, e^{-KESS \cdot Z_T}$$

$$I_{BOT} = I_{SFC}\, e^{-KESS(Z_T + \Delta z)}$$

$$I_{SFC} = \frac{I_{TOTAL}}{FD}\frac{\pi}{2}\sin\left(\pi\frac{t_D - t_U}{FD}\right)$$

$$KESS = KE_B + KE_{CHL} \cdot \sum_x \frac{B_x}{CCHL_x} + KE_{TSS} \cdot TSS$$

KESS = light extinction coefficient (m^{-1})
Z_T = distance from surface to the top of model layer (m)
IH_x = half-saturation light intensity for algal growth (langleys day^{-1})

I_{TOP}, I_{BOT} = light intensities at the top and bottom of model layer, respectively (langleys day^{-1})
I_{SFC} = light intensity at surface at time t (langley day^{-1})
I_{TOTAL} = total daily light intensity at surface (langley day^{-1})
FD = fractional daylength
t_D = time of day (in fractional days)
t_U = time of sunrise (in fractional days)
KE_B = background light extinction coefficient (m^{-1})
KE_{CHL} = light extinction coefficient for chlorophyll a (m^{-1} per mg CHL m^{-3})
$CCHL_x$ = carbon-to-chlorophyll ratio in algae (g C per g CHL)
KE_{TSS} = light extinction coefficient due to TSS (m^{-1} per g m^{-3})

The effect of light on algal growth was simulated using the Steele function, which always results in photo-inhibition at the surface under high light intensity. To relieve photo-inhibition, a Monod-type function with half-saturation light intensity is used in the present model. The present model also has the total suspended solids state variable, the light extinction coefficient is expressed to consist of three terms: background extinction, algal self-shading and extinction due to total suspended solids.

Effect of temperature on growth

$$
\begin{aligned}
f(T) &= \exp\left(-KTG1_x\,[T - TM_x]^2\right) \quad \text{when } T \le TM_x \\
&= \exp\left(-KTG2_x\,[TM_x - T]^2\right) \quad \text{when } T > TM_x
\end{aligned}
$$

where:
TM_x = optimal temperature for algal growth (°C)
$KTG1_x$ = effect of temperature below TM_x on algal growth (°C^{-2})
$KTG2_x$ = effect of temperature above TM_x on algal growth (°C^{-2}).

(b) Basal Metabolism

Basal metabolism is commonly considered to be an exponentially increasing function of temperature:

$$
BM_x = BMR_x \cdot \exp\left(KTB_x\,[T - TR_x]\right)
$$

where:
BMR_x = metabolic rate at reference temperature TR_x (day $^{-1}$)
KTB_x = effect of temperature on metabolism (C$^{\circ-1}$)
TR_x = reference temperature for metabolism (C°)

(c) Predation

The predation formulation is identical to basal metabolism. The difference in predation and basal metabolism lies in the distribution of the end products of these processes.

$PR_x = BPR_x \exp(KTB_x (T - TR_x))$
BPR_x = predation rate at TR_x (day $^{-1}$)
KTB_x = effect of temperature on predation (C^{o-1})
TR_x = reference temperature for predation (C°)

(d) Settling velocity

Reported algal settling rates typically range from 0.1 to 5 m d^{-1} (Bienfang et al., 1982; Riebesell, 1989; Waite et al., 1992). In part, this variation is a function of physical factors related to algal size, shape, and density (Hutchinson, 1967). The variability also reflects regulation of algal buoyancy as a function of nutritional status (Bienfang et al., 1982; Richardson and Cullen, 1995) and light (Waite et al., 1992). The algal settling rate employed in the model represents the total effect of all physiological and behavioral processes that result in the downward transport of phytoplankton. The settling rate employed, from 0.1 m d^{-1} to 0.9 m d^{-1}, was used in the model to optimize agreement of predicted and observed algae.

The calculation of TSS was based on the Sanford (2008) formulation of the sediment transport model described in Section III-4 of the report entitled: "Development of Hydrodynamic and Water Quality Models for the Lynnhaven River System" submitted to the Army Corps of Engineers, Norfolk District in March, 2009.

II-2. The Implementation of Habitat Restoration Plans

For this project, a total of 4 scenarios were executed in order to determine the impact of the removal of TSS and chlorophyll on two habitat restoration plans. These plans are known as "Plan A" (also the "Selected Plan") and "Plan B". Descriptions of the 4 scenarios are as follows:

Scenario 1 – execute UnTRIM to assess the impact of TSS removal caused by "Plan A"
Scenario 2 – execute UnTRIM to assess the impact of TSS removal caused by "Plan B"
Scenario 3 – execute ICM to assess the impact of chlorophyll removal caused by "Plan A"
Scenario 4 – execute ICM to assess the impact of chlorophyll removal caused by "Plan B"

Tables 1 and 2 show the acreages associated with each restoration site (locations for which are shown in Figure 2) for "Plan A" and "Plan B", respectively. Additionally, estimates of both the TSS removal rates (kg (TSS removed)/acre/month) and secondary production rates (kg (ash-free dry weight of animal biomass)/acre/month) are listed in Table 3 for all 3 types of habitat restoration. As these uptake rates vary seasonally, estimates are provided for each month of the year.

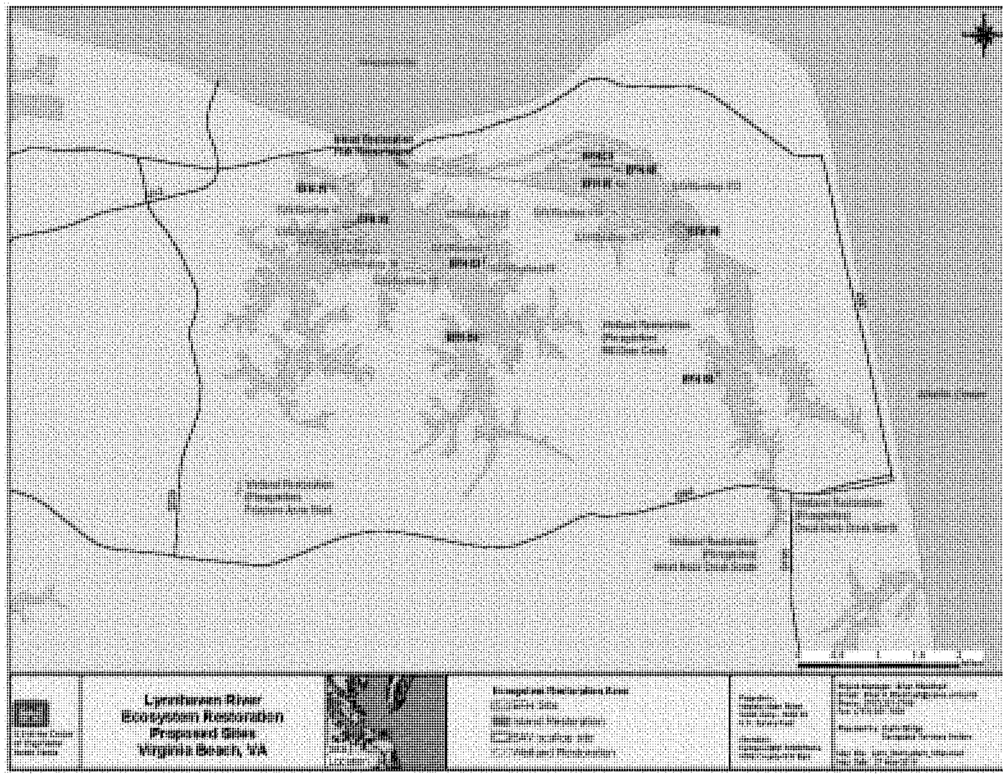

Figure 2. Lynnhaven River Ecosystem Restoration Proposed Sites (Courtesy, Norfolk District COE)

Table 1. Site names (locations of which are shown in Figure 2) and acreages for each site of the 3 habitat types for "Plan A". (source: Norfolk District COE).

Restoration Type	DESCRIPTION	Site_Name on Map	Min_Max	ACRES
SAV	Western Branch Lynn 1	SAV/Scallop #1	Max	3.985
SAV	Western Branch Lynn 2	SAV/Scallop #2	Max	6.672
SAV	Eastern Branch Lynn 1	SAV/Scallop #3	Max	1.393
SAV	Eastern Branch Lynn 2	SAV/Scallop #4	Max	1.049
SAV	Eastern Branch Lynn 3	SAV/Scallop #5	Max	2.351
SAV	Eastern Branch Lynn 4	SAV/Scallop #6	Max	10.859
SAV	Eastern Branch Lynn 5	SAV/Scallop #7	Max	5.248
SAV	Eastern Branch Lynn 6	SAV/Scallop #8	Max	13.618
SAV	Brock Cove SAV	SAV/Scallop #9	Max	6.935
SAV	Broad Bay 1	SAV/Scallop #10	Max	13.655
SAV	Broad Bay 3	SAV/Scallop #11	Max	22.424
SAV	Broad Bay 2	SAV/Scallop #12	Max	5.574
			Total SAV Acreage	93.763
Scallop	Eastern Branch Lynn 6	SAV/Scallop #8	Min	5.959
Scallop	Broad Bay 1	SAV/Scallop #10	Min	6.935
Scallop	Broad Bay 3	SAV/Scallop #11	Min	8.695
			Total Scallop Acreage	21.589
Fish Reef Low Profile	Pleasure House Creek	EFH #1		1.214
Fish Reef	Hill Point	EFH #2		6.865
Fish Reef Low Profile	Brock Cove	EFH #3		0.964
Fish Reef Low Profile	Brown Cove	EFH #4		1.525
Fish Reef High Profile	Broad Bay north	EFH #5		1.796
Fish Reef High Profile	Broad Bay north	EFH #6		1.794
Fish Reef High Profile	Broad Bay center	EFH #7		2.265
Fish Reef	Broad Bay Cove	EFH #8		14.306
Fish Reef High Profile	Linkhorn Bay	EFH #9		0.688
			Total Fish Reef Acreage	31.417

Table 2. Site names (locations of which are shown in Figure 2) and acreages for each site of the 3 habitat types for "Plan B" (source: Norfolk District COE).

Rest_Type	DESC	Site_Name on Map	Min_Max	ACRES
SAV	Western Branch Lynn 1	SAV/Scallop #1	Max	3.985
SAV	Western Branch Lynn 2	SAV/Scallop #2	Max	6.672
SAV	Eastern Branch Lynn 1	SAV/Scallop #3	Max	1.393
SAV	Eastern Branch Lynn 2	SAV/Scallop #4	Max	1.049
SAV	Eastern Branch Lynn 3	SAV/Scallop #5	Max	2.351
SAV	Eastern Branch Lynn 4	SAV/Scallop #6	Max	10.859
SAV	Eastern Branch Lynn 5	SAV/Scallop #7	Max	5.248
SAV	Eastern Branch Lynn 6	SAV/Scallop #8	Max	13.618
SAV	Brock Cove SAV	SAV/Scallop #9	Max	6.935
SAV	Broad Bay 1	SAV/Scallop #10	Max	13.655
SAV	Broad Bay 3	SAV/Scallop #11	Max	22.424
SAV	Broad Bay 2	SAV/Scallop #12	Max	5.574
			Total SAV Acreage	93.763
Scallop	Eastern Branch Lynn 6	SAV/Scallop #8	Min	5.959
Scallop	Broad Bay 1	SAV/Scallop #10	Min	6.935
Scallop	Broad Bay 3	SAV/Scallop #11	Min	8.695
			Total Scallop Acreage	21.589
~~Fish Reef Low Profile~~	~~Pleasure House Creek~~	~~EFH #1~~		0
~~Fish Reef~~	~~Hill Point~~	~~EFH #2~~		0
~~Fish Reef Low Profile~~	~~Brock Cove~~	~~EFH #3~~		0
~~Fish Reef Low Profile~~	~~Brown Cove~~	~~EFH #4~~		0
Fish Reef High Profile	Broad Bay north	EFH #5		1.796
Fish Reef High Profile	Broad Bay north	EFH #6		1.794
Fish Reef High Profile	Broad Bay center	EFH #7		2.265
Fish Reef	Broad Bay Cove	EFH #8		14.306
Fish Reef High Profile	Linkhorn Bay	EFH #9		0.688
			Total Fish Reef Acreage	20.849

Table 3. Estimates of TSS reduction rates and secondary production numbers for each habitat type in the Lynnhaven restoration (source: Norfolk District COE).

	Habitat Type							
Time (mos.)	SAV		Scallops		Fish Reefs (including oyster reefs)			
					Low Relief Reefs		High Relief Reefs	
	TSS	Secondary Production	TSS	Secondary Production	TSS	Secondary Production	TSS	Secondary Production
1 – January	6.07	80.94	22.09	20.23	446.60	72.50	552.65	89.71
2 – February	6.07	80.94	22.09	20.23	446.60	72.50	552.65	89.71
3 – March	12.14	161.87	44.19	40.46	893.06	144.99	1105.14	179.42
4 – April	18.21	242.81	66.28	60.70	1339.79	217.49	1657.95	269.13
5 – May	30.35	323.75	118.06	108.16	2232.98	362.48	2763.24	448.55
6 – June	54.63	678.33	185.13	169.62	3742.07	629.26	4630.70	778.69
7 – July	54.63	728.64	198.86	182.19	4019.36	652.46	4973.84	807.39
8 – August	54.63	728.64	198.86	182.19	4019.36	652.46	4973.84	807.39
9 – September	30.35	323.75	118.06	108.16	2232.98	362.48	2763.24	448.55
10 – October	18.21	242.81	66.28	60.70	1339.79	217.49	1657.95	269.13
11 – November	12.14	161.87	44.19	40.46	977.37	144.99	1209.46	179.42
12 – December	6.07	80.94	22.09	20.23	446.60	72.50	552.65	89.71
Total (annually)	**607**	**3835.29**	**1106.18**	**1013.33**	**22136.5**	**3601.55**	**27393.3**	**4456.82**
Avg. (monthly)	**50.58**	**319.61**	**92.18**	**84.44**	**1844.71**	**300.13**	**2282.77**	**371.40**

Notes: 1) All secondary production numbers are in ash-free dry weight of animal biomass and in kilograms/acre/month
2) All TSS reduction numbers are in kilograms of TSS removed/acre/month
3) The literature suggests a 10% trophic level transfer from primary to secondary level
4) For modeling purposes, one assumption is that there is 1% chlorophyll A per unit weight of plankton
5) The dry weight conversion of phytoplankton used is 10% of the wet weight.

There were 3 important setup steps that were required prior to performing these scenario runs:

Step 1 - Enhancements of model codes for the UnTRIM hydrodynamic model and the CE-QUAL-ICM water quality model were made, respectively, by adding sink terms to the equations computing the TSS and phytoplankton (in terms of carbon in biomass) concentrations. Sink term were added to the equation for the bottom layer only. Since most of the restoration sites are in shallow waters, the bottom layer is the entire water column in most affected model cells.

$(C'*V' - C*V)/\Delta t$ = advection terms + diffusion terms + growth & death terms (in case of phytoplankton carbon) – Sink term due to restored habitats

Where C′ and C are the concentrations (in gram per cubic meter) at new and old time steps respectively; V′ an V are the volume (in cubic meters) of the grid cell at new and old time steps, respectively: Δt is the time interval, in second, between the computation time steps. The first three groups of terms on the right hand side of the above equation exist in the original model formulation. The last term was computed with values provided by the Corps as shown in Table 3. For TSS reduction, the sink term in grams per second is:

Sink term = (1000*R)*A / (30*86400)

Where R is the TSS reduction rate in kg/acre/month, and varies monthly as shown in Table 3, and A is the area, in acres, of the restored habitat in the model computation cell.

For the chlorophyll reduction, the sink term, in terms of grams of carbon per second is

Sink term = (1000*SP/TE)*A/ (30*86400)

Where SP is the secondary production provided in Table 3, and TE is the tropic transfer efficiency, assumed to be 0.1 (10%, note in Table 3). The computed phytoplankton biomass is transferred to chlorophyll assuming a carbon to chlorophyll ratio of 60, which was determined in the calibration of the Lynnhaven River water quality model.

Step 2 - Using GIS technology, the physical extents of all restoration sites were superimposed onto the UnTRIM model grid to numerically characterize each relevant model cell.

The exact locations and spatial extents of the restoration sites could then be recorded. By intersecting the restoration site GIS layer with the VIMS model grid, we were able to identify exactly which cells among the more than 5,000 cells of the UnTRIM unstructured grid for the Lynnhaven River (Figure 1) fall entirely or partially within the area of restoration sites and to determine the acreage of restoration habitat in each of these cells.

Step 3 – Perform a year-long base case run for both hydrodynamic and water quality models using the calibration year of 2006. For the hydrodynamic base case execution, TSS concentrations at all 16 Lynnhaven VA-DEQ monitoring stations are saved throughout calendar year 2006. For the water quality base case execution, chlorophyll concentrations at all 16 Lynnhaven VA-DEQ monitoring stations are saved throughout calendar year 2006. These base case results are then later compared to the results from Scenario Runs 1-4 to assess the impacts caused by the restoration sites.

III. Scenario run results

III-1. TSS removal

The prediction of TSS by the Lynnhaven UnTRIM hydrodynamic model used calendar year 2006 for its calibration. This calibration occurred by comparing TSS observations against model predictions at the 16 Lynnhaven River VA-DEQ stations shown in Figure 1. These comparisons throughout 2006 are shown for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches, respectively, in Figures 3 through 5. This calibration simulation of the model, not invoking any TSS removal due to habitat construction, was then used as the "base case" to compare to Scenarios 1 and 2 to assess TSS removal.

III-1-1. TSS removal resulting from "Plan A" habitat restoration – Scenario 1

The UnTRIM hydrodynamic model was used to simulate Scenarios 1 and 2 for calendar year 2006 for comparison to the base case. The impact of "Plan A" is the difference (Plan A minus base case) for the VA-DEQ Lynnhaven stations grouped branch-by-branch (Figures 6 through 8). This difference, in effect, represents the removal of TSS due to the habitat restoration modeled for "Plan A". One way to assess the TSS removal is to compare the average of this difference over the entire year for each Lynnhaven VA-DEQ station with the average predicted base case value for that station, as shown in Tables 4 through 6.

Tables 4 and 5 display the average predicted base case TSS at VA-DEQ stations in the Western and Eastern Branches of the Lynnhaven and it can be seen that these range from 11 to 22 mg/l. The removal of TSS resulting from the Plan A restoration ranges from 0.3 to 8.0 mg/l at stations in these 2 branches, and the percentage of TSS removal ranges up to 44% in the Lower Eastern Branch. In general, the reduction percentage decreases moving upstream.

In contrast, Table 6 shows average predicted base case TSS values in the Broad Bay/Linkhorn Bay Branch as much lower, ranging from 6.1 to 9.5 mg/l. TSS reductions resulting from the Plan A restoration remain high, however, ranging from 3.0 to 7.1 mg/l. Consequently, in this branch, the percentage of reduction is quite high, ranging from 46% to 74%, and is generally increasing moving downstream.

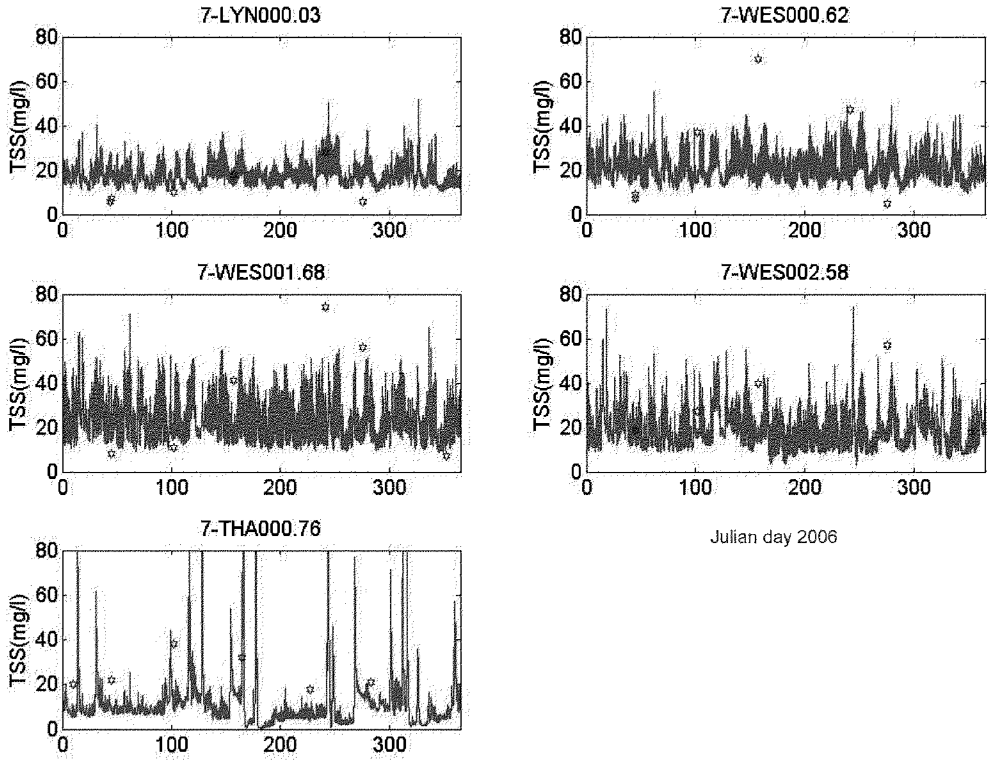

Figure 3. TSS observations (blue symbols) and TSS model predictions (red lines) shown for Lynnhaven Western Branch stations for 2006.

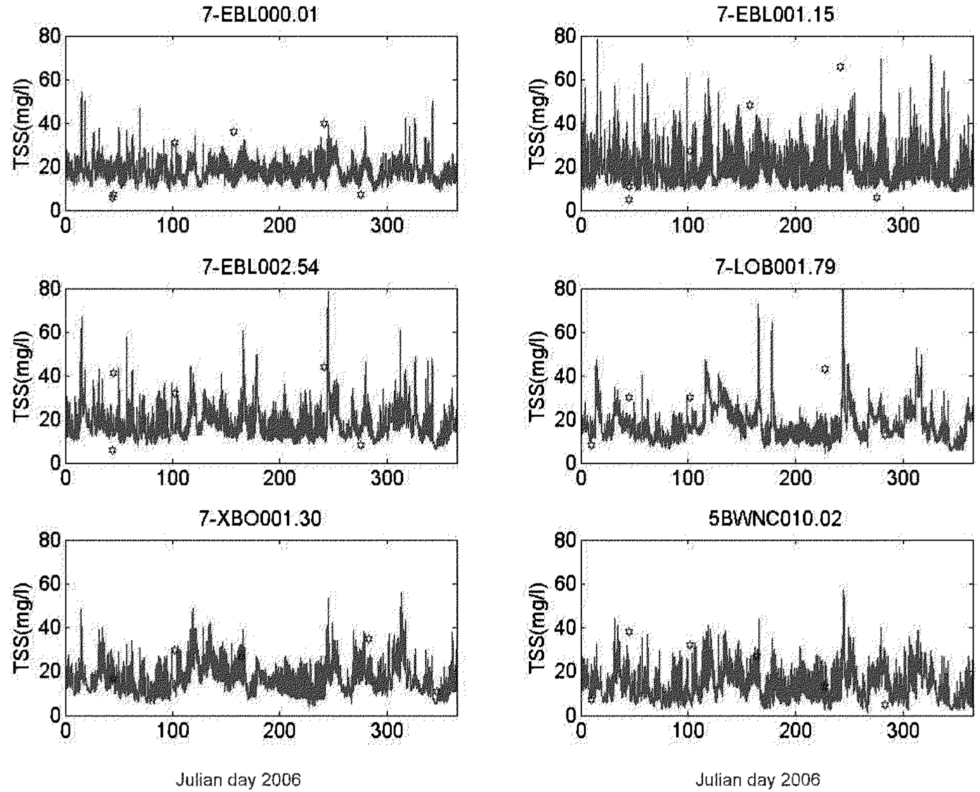

Figure 4. TSS observations (blue symbols) and TSS model predictions (red lines) shown for Lynnhaven Eastern Branch stations for 2006.

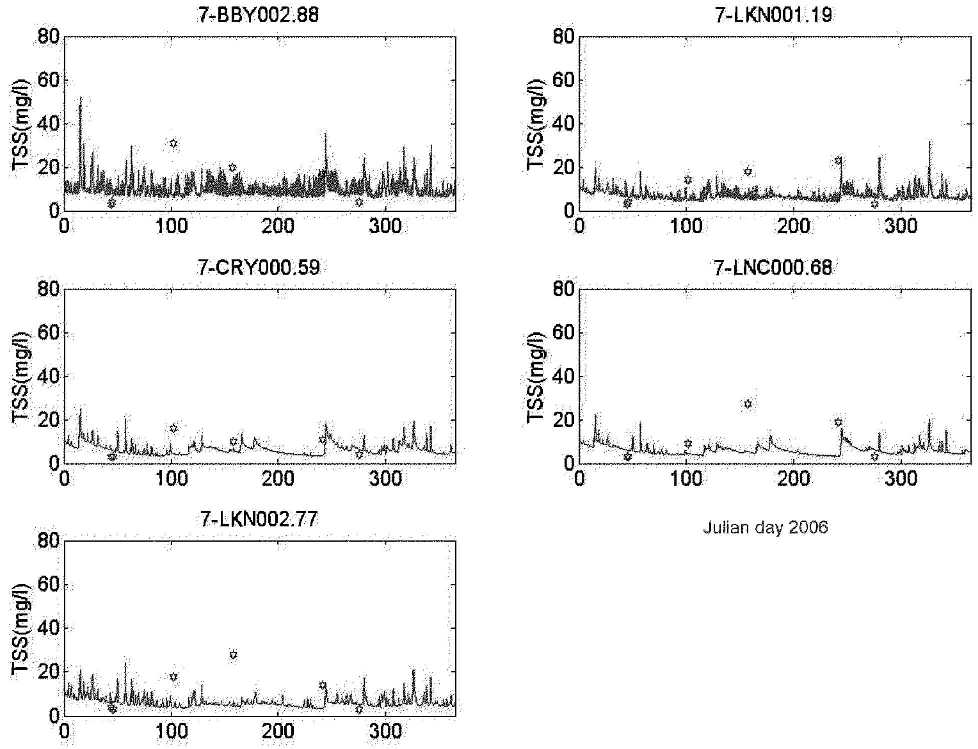

Figure 5. TSS observations (blue symbols) and TSS model predictions (red lines) shown for Lynnhaven Broad Bay/Linkhorn Bay Branch stations for 2006.

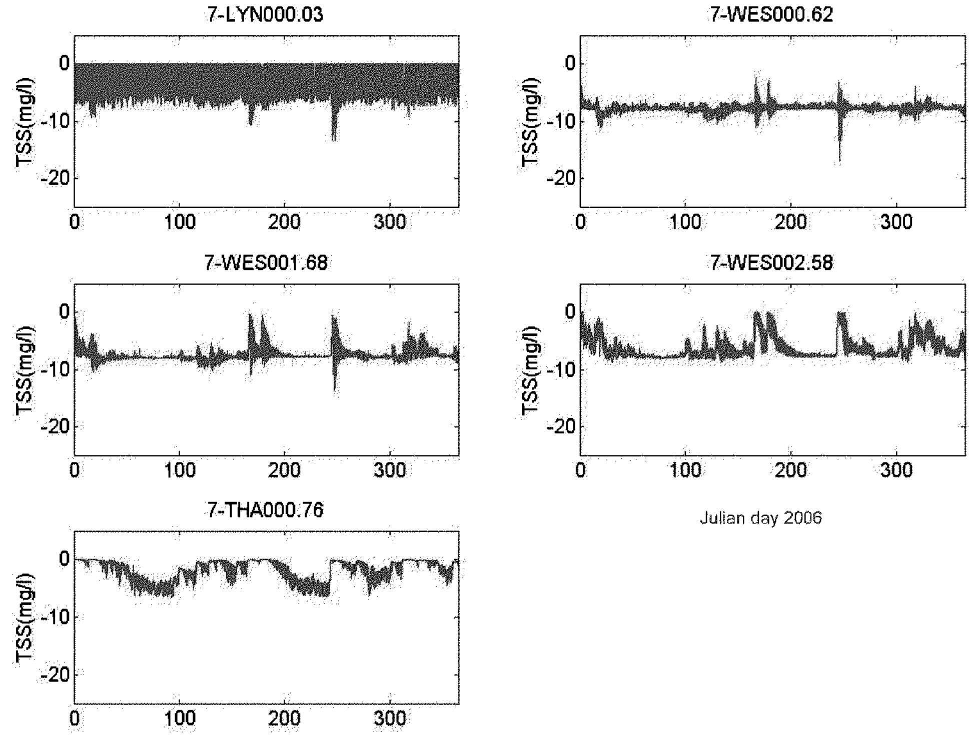

Figure 6. TSS differences (Plan A minus Base Case) shown for the Lynnhaven River Western Branch VA-DEQ stations for year 2006.

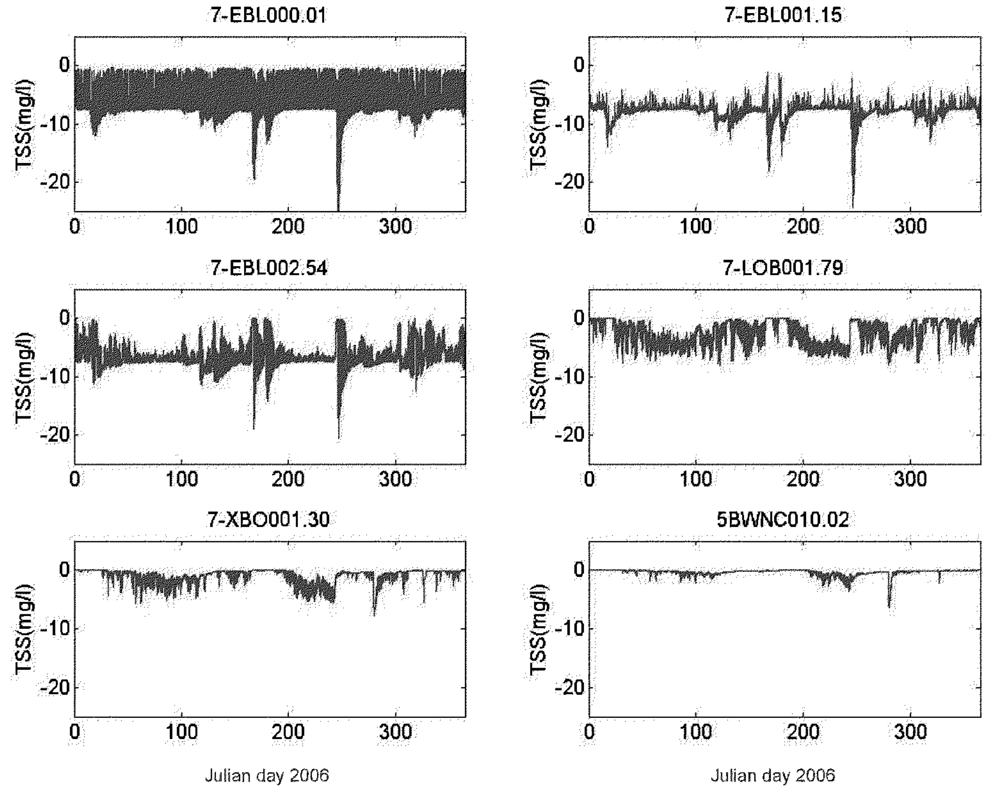

Figure 7. TSS differences (Plan A minus Base Case) shown for the Lynnhaven River Eastern Branch VA-DEQ stations for year 2006.

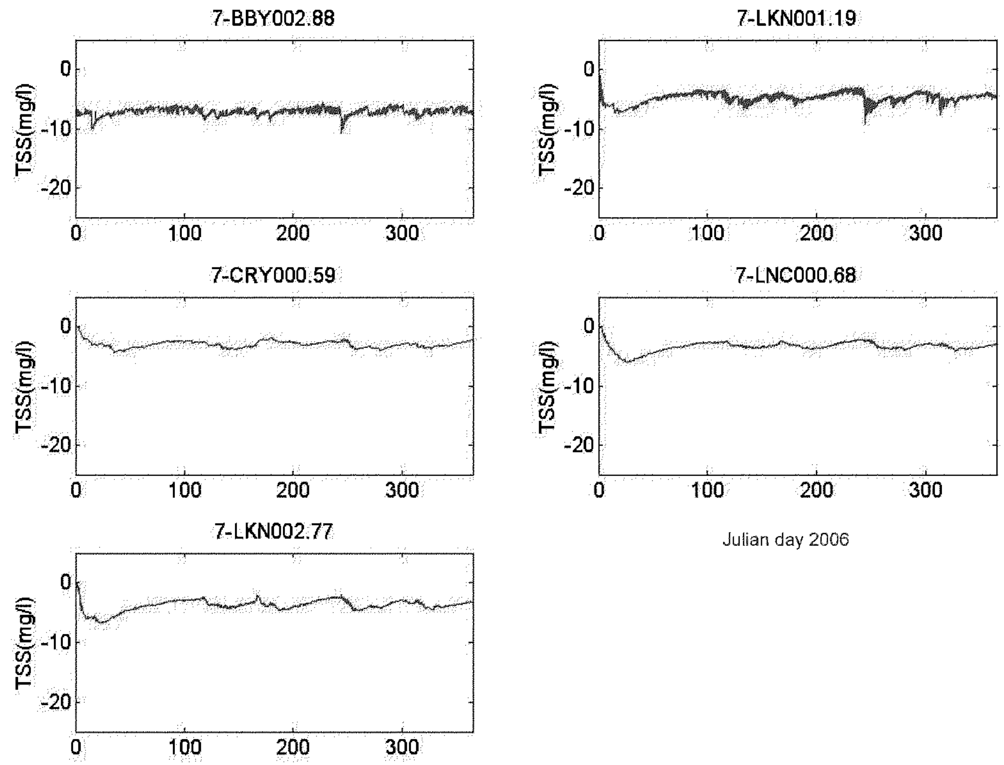

Figure 8. TSS differences (Plan A minus Base Case) shown for the Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations for year 2006.

Table 4. The average TSS reduction at Lynnhaven River Western Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-LYN000.03	18	3.1 (BC*)	17%
7-WES000.62	21	7.8	38%
7-WES001.68	22	7.3	33%
7-WES002.58	18	6.1	36%
7-THA000.76	11	1.8	16%

BC* - Suspected impact from fixed boundary condition in the Bay

Table 5. The average TSS reduction at Lynnhaven River Eastern Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-EBL000.01	18	5.9	33%
7-EBL001.15	18	8.0	44%
7-EBL002.54	18	6.4	36%
7-LOB001.79	18	2.4	14%
7-XBO001.30	16	1.0	6.1%
5BWNC010.02	14	0.3	2.5%

Table 6. The average TSS reduction at Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-BBY002.88	9.5	7.1	74%
7-LKN001.19	7.0	4.8	68%
7-CRY000.59	6.5	3.0	46%
7-LNC000.68	6.1	3.4	55%
7-LKN002.77	6.3	3.8	60%

III-1-2. TSS removal resulting from "Plan B" habitat restoration – Scenario 2

First, it should be noted that Plan B differs from Plan A only in that the former excludes the 4 low profile fish reefs (EFH#1, EFH#2, EFH#3, and EFH#4) listed in Tables 1 and 2. These sites are all located near the Inlet and the Lower Eastern Branch. The impact of the "Plan B" restoration on TSS removal is shown by the differences of the time series (Plan B minus base case) plotted from 2006 simulations. These differences are plotted for all 16 VA-DEQ Lynnhaven stations and are grouped branch-by-branch in Figures 9, 10, and 11, respectively, for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches.

As was done for the assessment of the Scenario 1 (i.e., "Plan A") results, part of the assessment of the TSS removal impact of Scenario 2 (i.e., "Plan B") is to compare the average of this difference over the entire year for each Lynnhaven VA-DEQ station with the average predicted base case value for that station, as shown in Tables 7 through 9.

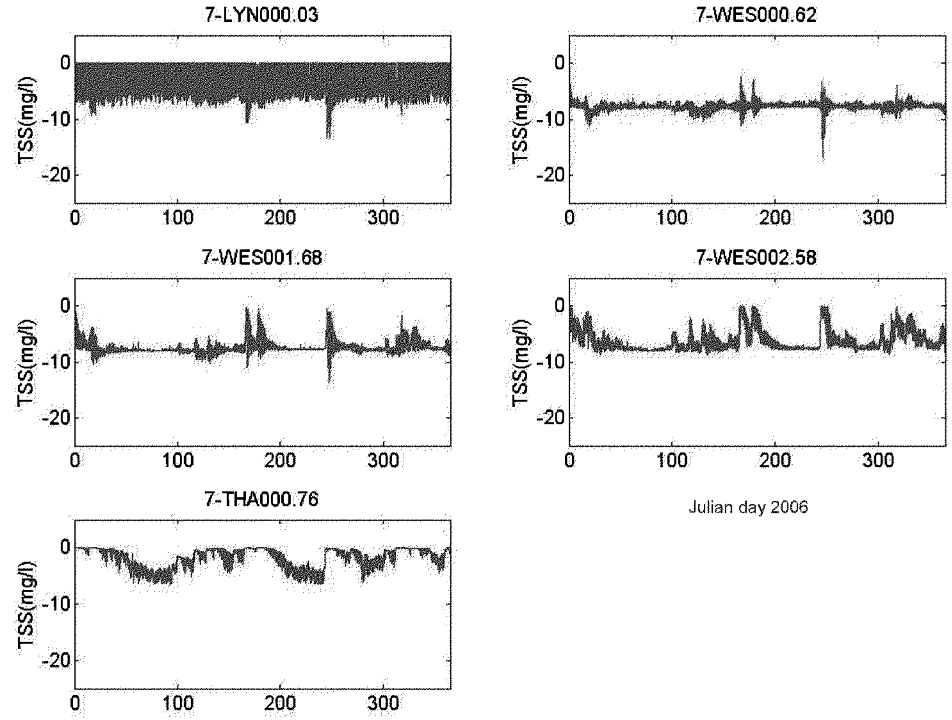

Figure 9. TSS differences (Plan B minus Base Case) shown for the Lynnhaven River Western Branch VA-DEQ stations for year 2006.

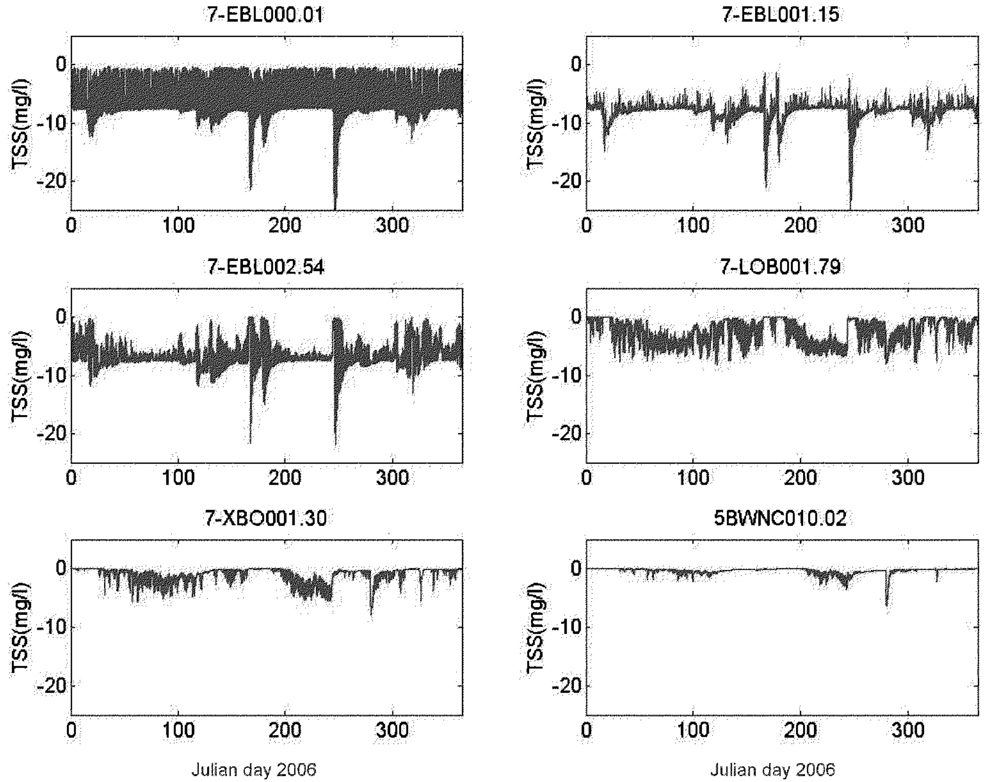

Figure 10. TSS differences (Plan B minus Base Case) shown for the Lynnhaven River Eastern Branch VA-DEQ stations for year 2006.

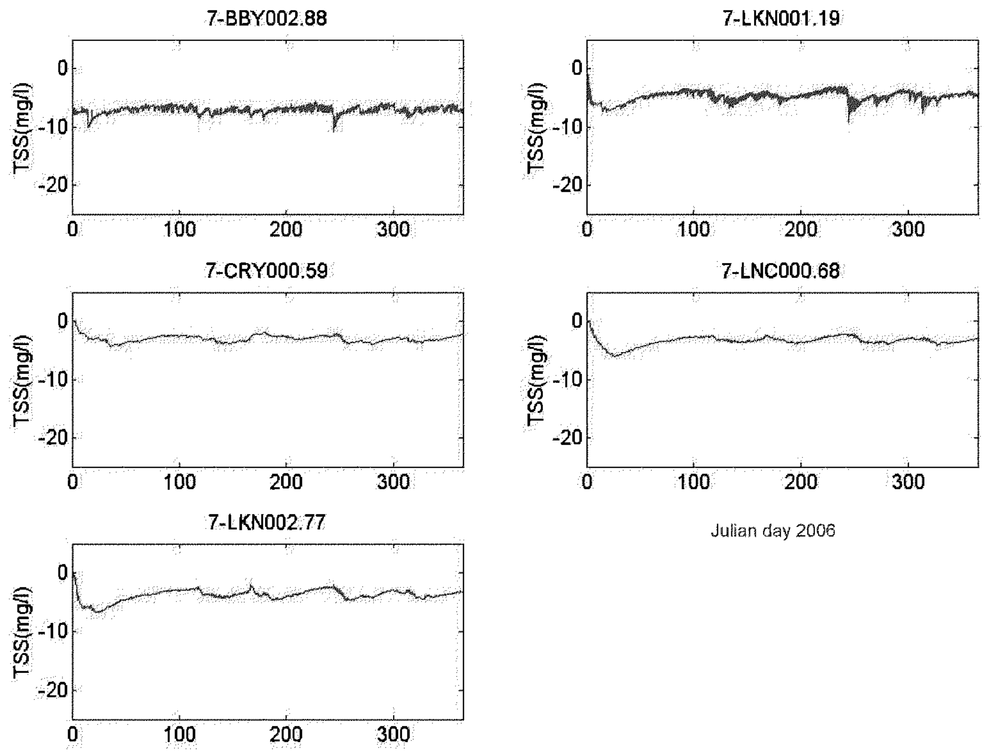

Figure 11. TSS differences (Plan B minus Base Case) shown for the Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations for year 2006.

Table 7. The average TSS reduction at Lynnhaven River Western Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-LYN000.03	18	3.1 (BC*)	17%
7-WES000.62	21	7.8	38%
7-WES001.68	22	7.3	33%
7-WES002.58	18	6.1	36%
7-THA000.76	11	1.8	16%

BC* - Suspected impact from fixed boundary condition in the Bay

Table 8. The average TSS reduction at Lynnhaven River Eastern Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-EBL000.01	18	5.9	33%
7-EBL001.15	18	7.9	43%
7-EBL002.54	18	6.3	36%
7-LOB001.79	18	2.4	14%
7-XBO001.30	16	1.0	6.0%
5BWNC010.02	14	0.3	2.4%

Table 9. The average TSS reduction at Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case TSS (mg/l)	TSS Reduction (mg/l)	Percentage of Reduction
7-BBY002.88	9.5	7.1	74%
7-LKN001.19	7.0	4.8	68%
7-CRY000.59	6.5	3.0	46%
7-LNC000.68	6.1	3.4	55%
7-LKN002.77	6.3	3.8	60%

III-2. Chlorophyll removal

The prediction of chlorophyll by the Lynnhaven CE-QUAL-ICM water quality model used calendar year 2006 for its calibration. This calibration occurred by comparing chlorophyll observations against model predictions at the 16 Lynnhaven River VA-DEQ stations shown in Figure 1. These comparisons throughout 2006 are shown for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches, respectively, in Figures 12 through 14. This calibration simulation of the model, not invoking any chlorophyll removal due to habitat construction, was then used as the "base case" to compare to Scenarios 3 and 4 to assess chlorophyll removal.

As part of the specifications for Scenarios 3 and 4, in addition to the "Plan A" and "Plan B" restoration design specifications, the results of the assessed impacts of these plans on TSS levels (i.e., results of Scenarios 1 and 2) were factored in. This was done by reducing the sediment load by 40% throughout the domain for both Scenarios 3 and 4.

III-2-1. Chlorophyll removal resulting from "Plan A" habitat restoration – Scenario 3

The CE-QUAL-ICM water quality model was used to simulate Scenarios 3 and 4 for calendar year 2006 for comparison to the base case. The impact of "Plan A" is the difference (Plan A minus base case) for the VA-DEQ Lynnhaven stations grouped branch-by-branch (Figures 15 through 17). This difference, in effect, represents the removal of chlorophyll due to the habitat restoration modeled for "Plan A". One way to assess the chlorophyll removal is to compare the average of this difference over the entire year for each Lynnhaven VA-DEQ station with the average predicted base case value for that station, as shown in Tables 10 through 12.

Tables 10, 11, and 12 display the average predicted base case chlorophyll concentrations at VA-DEQ stations, respectively, in the Western, Eastern, and Broad Bay/Linkhorn Bay Branches of the Lynnhaven and it can be seen that these range from 7.7 to 15.0 μg/l for calendar year 2006. The removal of chlorophyll resulting from the Plan A restoration ranges from 1.4 to 4.0 μg/l at stations in these 3 branches, and the percentage of chlorophyll removal ranges from 12 to 30% over these 3 branches.

Compared with the results of the TSS reductions ranges shown in Section III-1, the chlorophyll reductions showed much less variation from branch to branch. Averages of the percentages of reduction shown in Tables 10 through 12 at the DEQ stations in the Western, Eastern, and Broad Bay/Linkhorn Bay Branches, respectively, are 25.2%, 17.7%, and 22.4%.

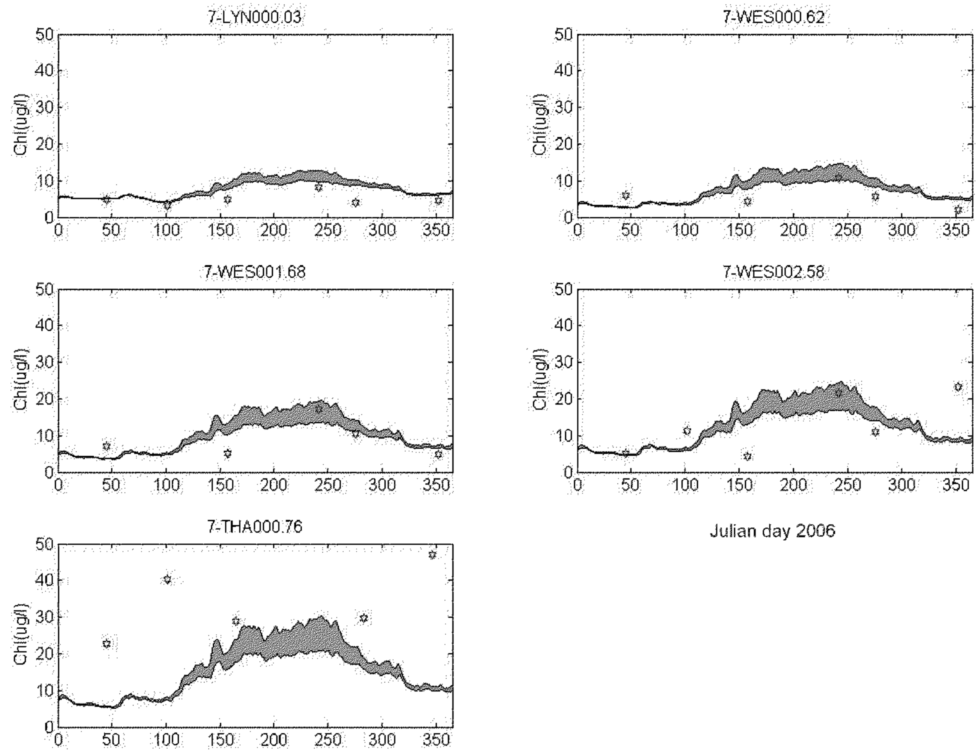

Figure 12. Chlorophyll observations (red symbols) and chlorophyll model predictions (grey areas) shown for Lynnhaven Western Branch stations for 2006.

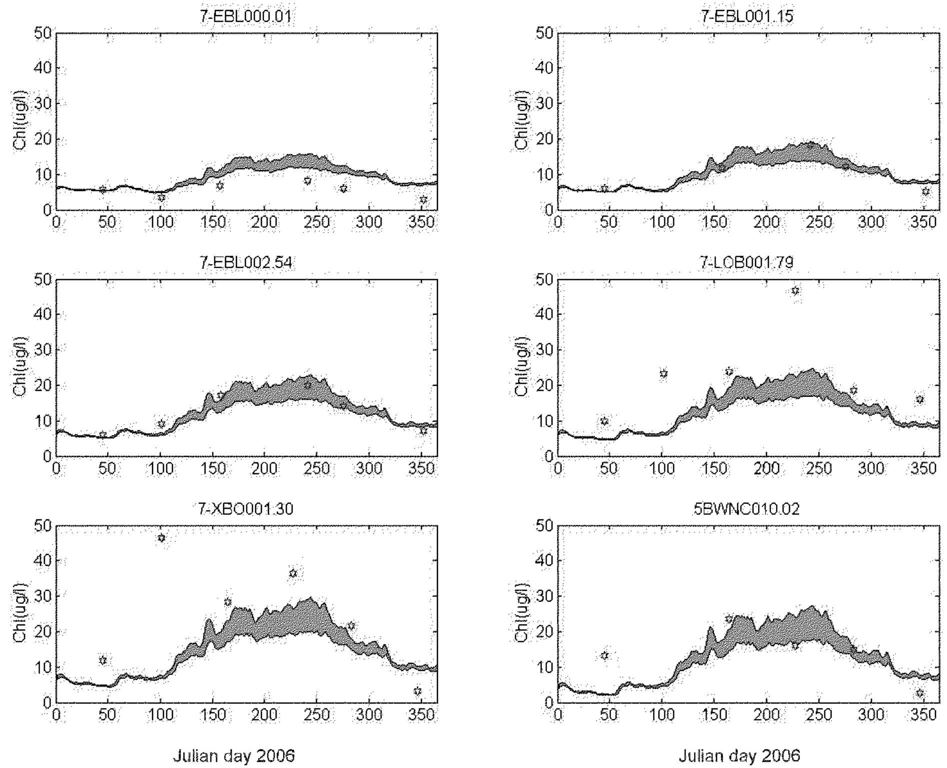

Figure 13. Chlorophyll observations (red symbols) and chlorophyll model predictions (grey areas) shown for Lynnhaven Eastern Branch stations for 2006.

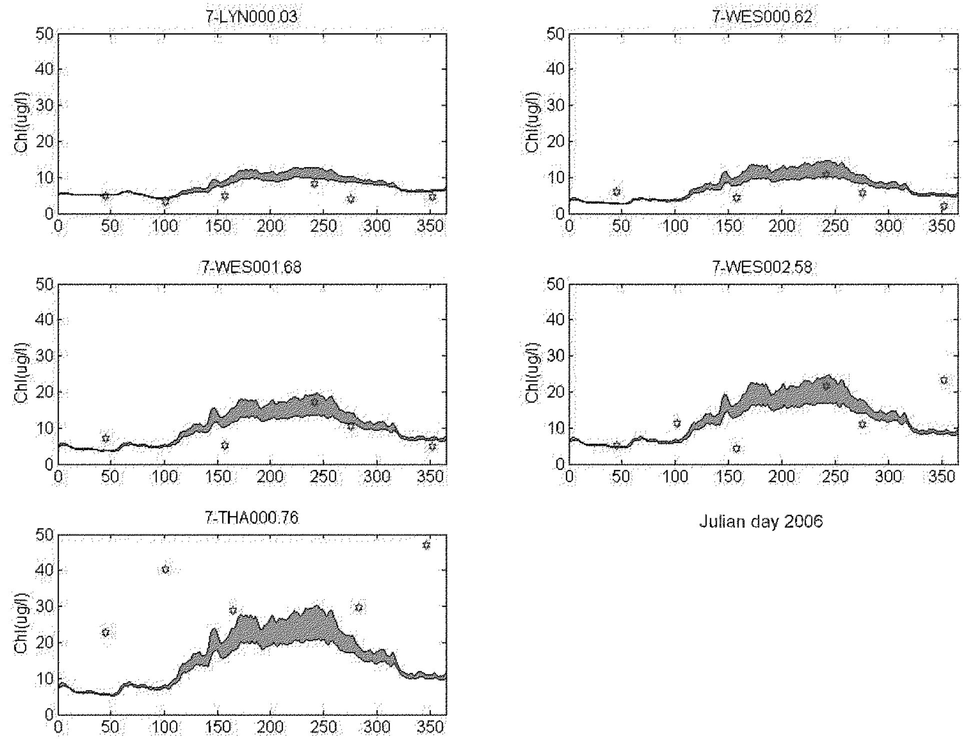

Figure 14. Chlorophyll observations (red symbols) and chlorophyll model predictions (grey areas) shown for Lynnhaven Broad Bay/Linkhorn Bay Branch stations for 2006.

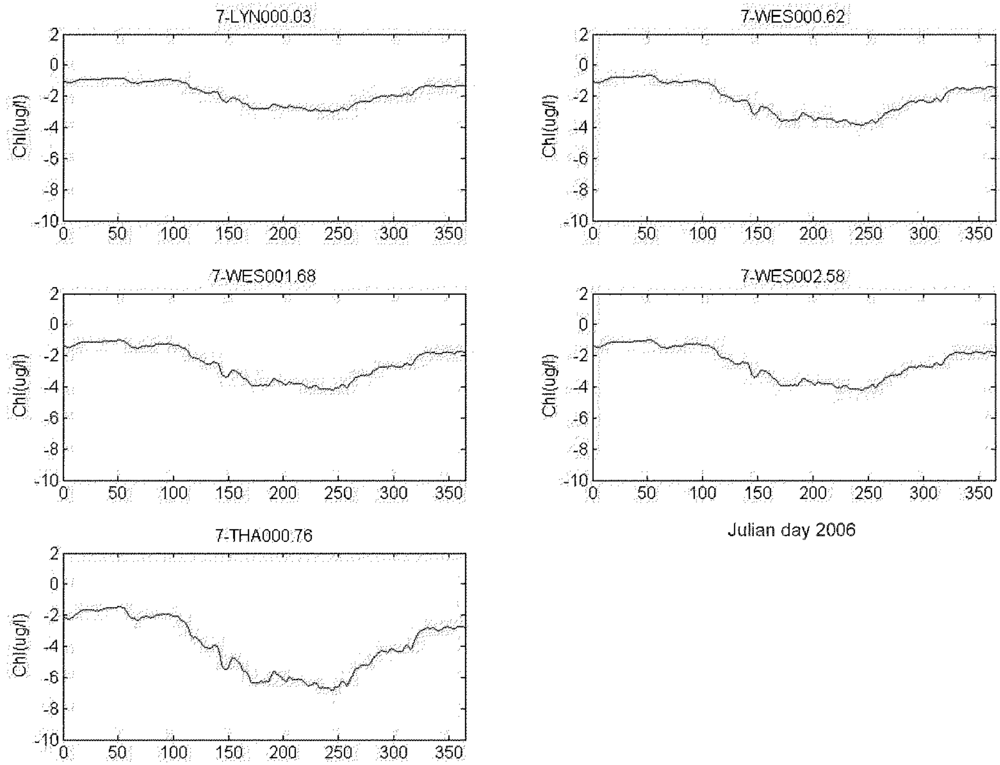

Figure 15. Chlorophyll differences (Plan A minus Base Case) shown for the Lynnhaven River Western Branch VA-DEQ stations for year 2006.

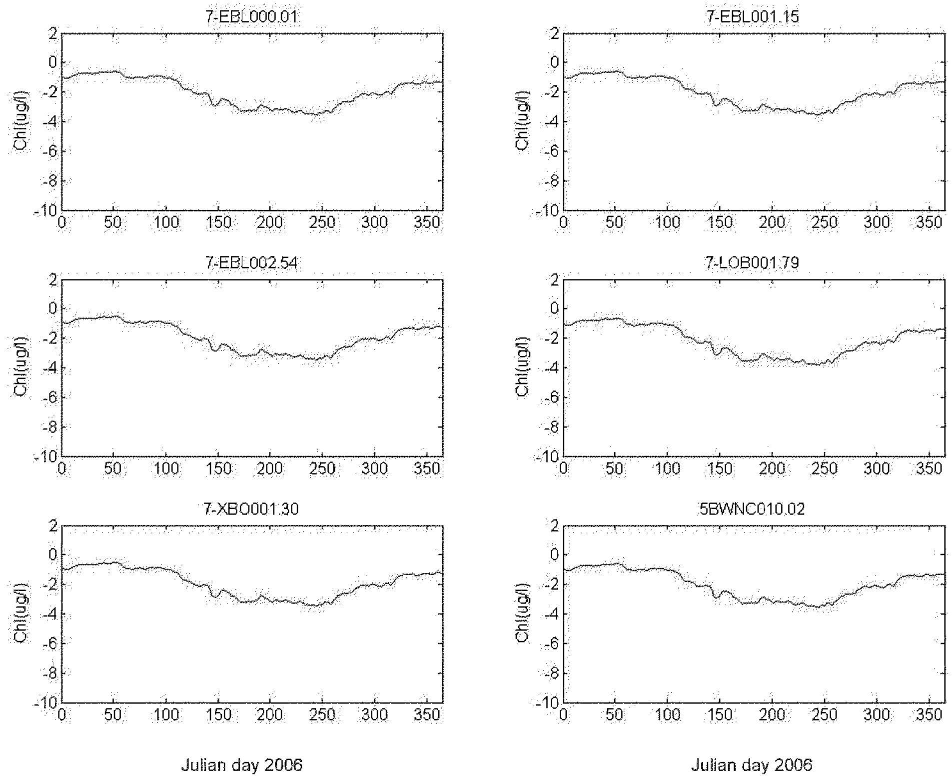

Figure 16. Chlorophyll differences (Plan A minus Base Case) shown for the Lynnhaven River Eastern Branch VA-DEQ stations for year 2006.

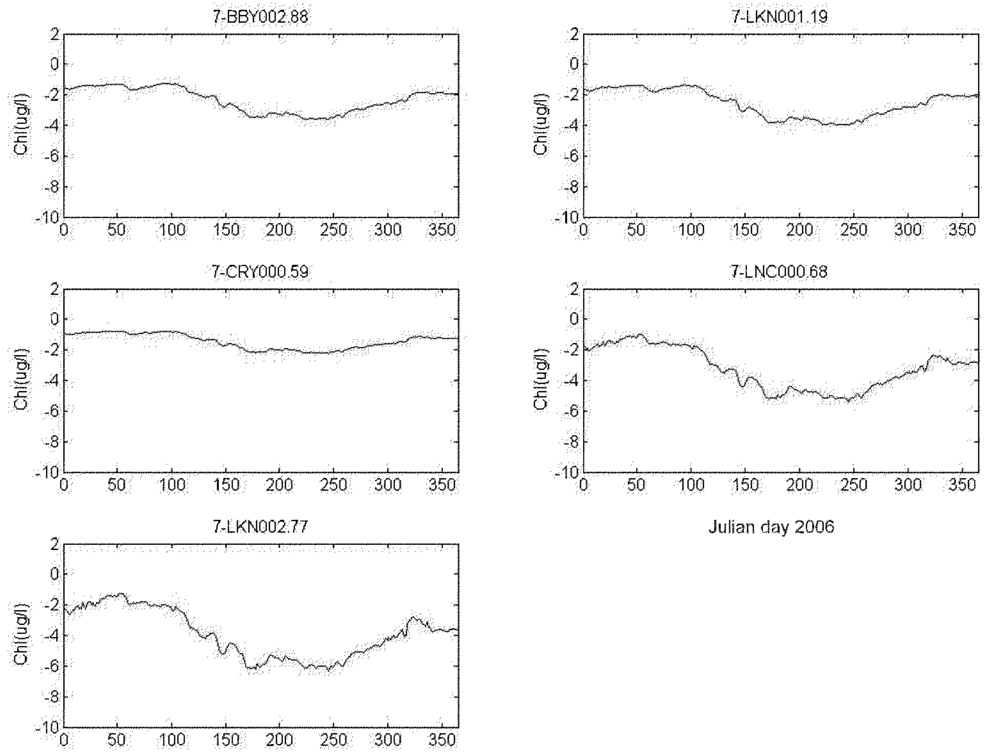

Figure 17. Chlorophyll differences (Plan A minus Base Case) shown for the Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations for year 2006.

Table 10. The average chlorophyll reduction at Lynnhaven River Western Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case Chlorophyll (µg/l)	Chlorophyll Reduction (µg/l)	Percentage of Reduction
7-LYN000.03	7.7	1.8 (BC*)	24%
7-WES000.62	7.3	2.2	30%
7-WES001.68	9.8	2.5	25%
7-WES002.58	12.3	2.5	20%
7-THA000.76	15.0	4.0	27%

BC* - Suspected impact from fixed boundary condition in the Bay

Table 11. The average chlorophyll reduction at Lynnhaven River Eastern Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case Chlorophyll (µg/l)	Chlorophyll Reduction (µg/l)	Percentage of Reduction
7-EBL000.01	9.1	2.0	22%
7-EBL001.15	10.3	2.0	19%
7-EBL002.54	11.9	1.9	16%
7-LOB001.79	12.3	2.2	18%
7-XBO001.30	14.2	1.9	14%
5BWNC010.02	11.9	2.0	17%

Table 12. The average chlorophyll reduction at Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations in 2006 resulting from the Plan A restoration.

Station	Avg. Predicted Base Case Chlorophyll (μg/l)	Chlorophyll Reduction (μg/l)	Percentage of Reduction
7-BBY002.88	9.6	2.3	24%
7-LKN001.19	10.3	2.6	25%
7-CRY000.59	12.9	1.4	12%
7-LNC000.68	13.6	3.2	24%
7-LKN002.77	14.6	3.9	27%

III-2-2. Chlorophyll removal resulting from "Plan B" habitat restoration – Scenario 4

The CE-QUAL-ICM water quality model was used to simulate Scenario 4 for calendar year 2006 for comparison to the base case, as was done earlier for Scenario 3. The impact of "Plan B" is the difference (Plan B minus base case) for the VA-DEQ Lynnhaven stations grouped branch-by-branch (Figures 18 through 20). This difference, in effect, represents the removal of chlorophyll due to the habitat restoration modeled for "Plan B". One way to assess the chlorophyll removal is to compare the average of this difference over the entire year for each Lynnhaven VA-DEQ station with the average predicted base case value for that station, as shown in Tables 13 through 15.

Tables 13, 14, and 15 display the average predicted base case chlorophyll concentrations at VA-DEQ stations, respectively, in the Western, Eastern, and Broad Bay/Linkhorn Bay Branches of the Lynnhaven and it can be seen that these range from 7.7 to 15.0 μg/l for calendar year 2006. The removal of chlorophyll resulting from the Plan B restoration ranges from 1.1 to 3.8 μg/l at stations in these 3 branches, and the percentage of chlorophyll removal ranges from 8% to 25% over these 3 branches.

Compared with the results of the chlorophyll reductions resulting from the Scenario 3 (Plan A) assessment shown in Section III-2-1, the chlorophyll reductions in the results of Scenario 4 (Plan B) were slightly less in each branch. For Scenario 4, the averages of the percentages of reduction shown in Tables 13 through 15 at the DEQ stations in the Western, Eastern, and Broad Bay/Linkhorn Bay Branches, respectively, are 21.0%, 14.3%, and 19.8%, less than the 25.2%, 17.7%, and 22.4% shown earlier for Scenario 3 (Plan A impact).

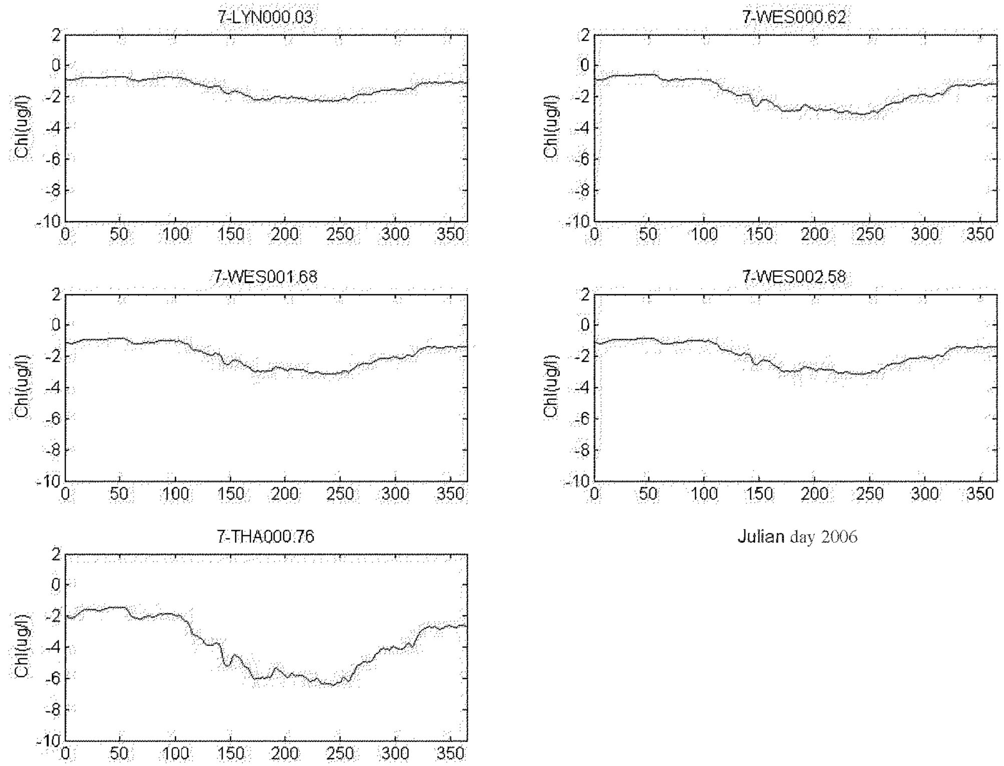

Figure 18. Chlorophyll differences (Plan B minus Base Case) shown for the Lynnhaven River Western Branch VA-DEQ stations for year 2006.

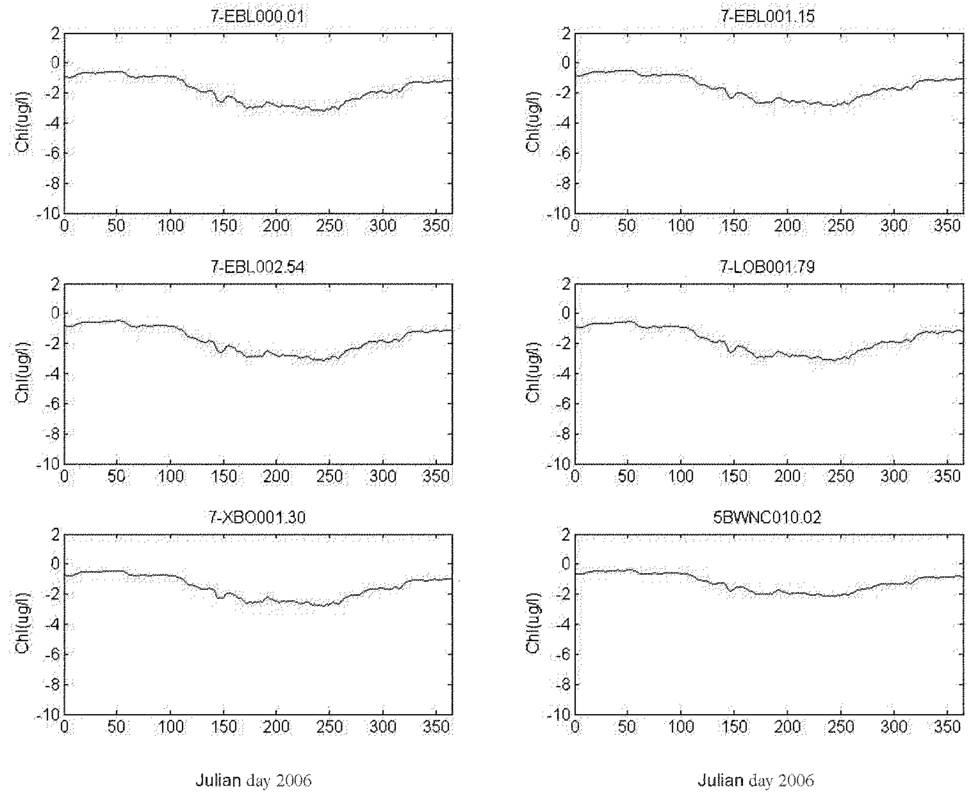

Figure 19. Chlorophyll differences (Plan B minus Base Case) shown for the Lynnhaven River Eastern Branch VA-DEQ stations for year 2006.

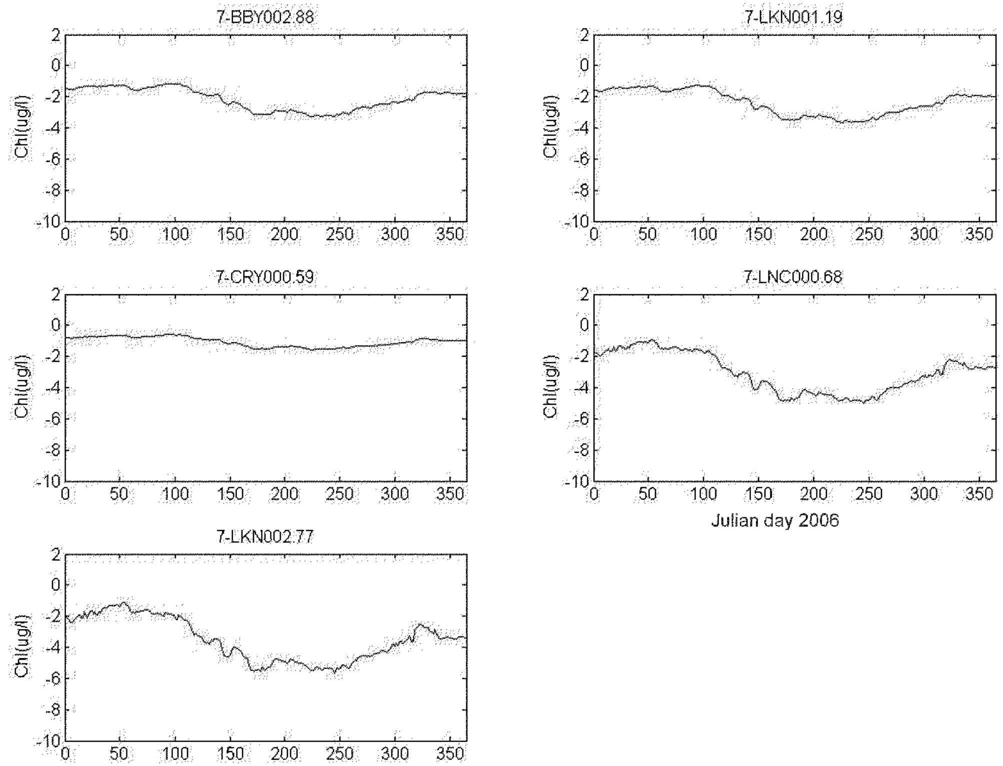

Figure 20. Chlorophyll differences (Plan B minus Base Case) shown for the Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations for year 2006.

Table 13. The average chlorophyll reduction at Lynnhaven River Western Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case Chlorophyll (µg/l)	Chlorophyll Reduction (µg/l)	Percentage of Reduction
7-LYN000.03	7.7	1.4 (BC*)	19%
7-WES000.62	7.3	1.8	25%
7-WES001.68	9.8	1.9	20%
7-WES002.58	12.3	1.9	16%
7-THA000.76	15.0	3.8	25%

BC* - Suspected impact from fixed boundary condition in the Bay

Table 14. The average chlorophyll reduction at Lynnhaven River Eastern Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case Chlorophyll (µg/l)	Chlorophyll Reduction (µg/l)	Percentage of Reduction
7-EBL000.01	9.1	1.8	20%
7-EBL001.15	10.3	1.6	16%
7-EBL002.54	11.9	1.7	15%
7-LOB001.79	12.3	1.8	14%
7-XBO001.30	14.2	1.5	11%
5BWNC010.02	11.9	1.2	10%

Table 15. The average chlorophyll reduction at Lynnhaven River Broad Bay/Linkhorn Bay Branch VA-DEQ stations in 2006 resulting from the Plan B restoration.

Station	Avg. Predicted Base Case Chlorophyll (μg/l)	Chlorophyll Reduction (μg/l)	Percentage of Reduction
7-BBY002.88	9.6	2.1	22%
7-LKN001.19	10.3	2.4	23%
7-CRY000.59	12.9	1.1	8%
7-LNC000.68	13.6	3.0	22%
7-LKN002.77	14.6	3.5	24%

IV. Summary and Discussion

For this project, formulations have been developed that predict spatial and temporal distributions of TSS and chlorophyll reductions throughout the Lynnhaven River that are caused by site-specific habitat restorations of essential fish habitat (including oyster reefs), submerged aquatic vegetation (SAV), and scallop sites. These formulations depend on the application of hydrodynamic and water quality models calibrated respectively for TSS and chlorophyll concentrations as well as the size of the habitat restoration area. These models have been enhanced to include sink terms for TSS and chlorophyll that are activated in those portions of the numerical model domain that intersect the habitat restoration sites.

In order to examine the spatial distribution of TSS removal throughout the Lynnhaven's three branches, year-long time averages of 1) the predicted base case TSS concentrations and 2) the TSS reductions due to both habitats "Plan A" and "Plan B" were calculated at each of 16 Lynnhaven VA-DEQ stations. These averages, shown in Tables 4 through 6 for Plan A and in Tables 7 through 9 for Plan B, yield TSS reduction percentages ranging from 2.5% at Station 5BWNC010.02 (in the upper Eastern Branch) to 74% at Station 7-BBY002.88 (in Broad Bay). For both Plan A and Plan B, the average TSS reductions for the Western, Eastern, and Broad Bay/Linkhorn Bay Branches are, respectively, 28.0%, 22.4%, and 60.6%.

In order to assess the spatial distribution of chlorophyll removal throughout the Lynnhaven's three branches, year-long time averages of 1) the predicted base case chlorophyll concentrations and 2) the chlorophyll reductions due to both habitats "Plan A" and "Plan B" were calculated at each of 16 Lynnhaven VA-DEQ stations. These averages, shown in Tables 10 through 12 for Plan A and in Tables 13 through 15 for Plan B, yield chlorophyll reduction percentages ranging from 10% at Station 5BWNC010.02 (in the upper Eastern Branch) to 30% at Station 7-WES000.62 (in the Lower Western Branch). For Plan A, the average chlorophyll reductions for the Western, Eastern, and Broad Bay/Linkhorn Bay branches are, respectively, 25.2%, 17.7%, and 22.4%. For Plan B, these reductions are 21.0%, 14.3%, and 19.8%. Compared to the TSS reductions, the percentages of chlorophyll reductions are more moderate, and spatially uniform. While the secondary production of the restored habitat reduces the phytoplankton population, the reduced TSS concentration promotes the phytoplankton growth instead, thus dampening the impact of the uptake by the restored habitat.

Overall, TSS and chlorophyll reductions were indeed achieved when the ecosystem restoration were implemented, as shown above. The scenario run results for the stations in Broad Bay/Linkhorn Bay (Tables 6 and 9), where the base case TSS concentrations are low and the percentage reductions are high, should be interpreted with caution. In fact, these reduction results should be interpreted as the maximum benefits achievable. In reality, the TSS reduction rates and the secondary production should decrease as the water column concentrations of TSS and phytoplankton decrease. The specification of sink terms independent of water column concentrations will result in over-estimation of reduction effects when water column concentrations are lower than some yet-to-be-determined critical values. To be more precise, the magnitudes of sink terms in the model equations should be dependent on the water column concentrations. Furthermore, some of the TSS may get resuspended after deposition by the filter feeders. The process and magnitude of the resuspension are not yet completely understood, and not included in the current specification of the sink term. The TSS reduction can also affect the light field in the water column and, hence, affect the chlorophyll concentration in a feedback system. Much more research is required to formulate the functional relationships between the sink terms and water column concentrations, and its feedback mechanism, which is beyond the scope of this project. On the other hand, the US EPA is giving serious consideration to the inclusion of the effect of filter feeders into their formulation of the primary Bay cleanup plan, the Bay Total Maximum Daily Load (TMDL) (Chesapeake Bay Journal, June 2010). It is anticipated that more research on these issues will develop.

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Appendix A. Documentation of Unprocessed Request of Incorporation of Revised Specifications of Secondary Production Numbers

On September 20, 2010 the numerical modeling group received a request from Norfolk District personnel asking if new secondary production numbers could be incorporated into the water quality scenarios.

Due to the time constraints associated with this project, and given the information that post-simulation corrections could be made once the final numbers were obtained, the revised specifications were not incorporated into the scenarios.

These specifications are listed in Table A-1 on the next 2 pages for purposes of documentation.

Table A-1. Specification Table provided by Norfolk District Personnel showing the TSS uptake and secondary productivity numbers, with a request for revision to the secondary production numbers for scallops.

Time (months)	SAV TSS	SAV Sec Prod	Scallops TSS	Scallops Sec Prod	Wetlands TSS	Wetlands Sec Prod	Fish Reffs LRR TSS	Fish Reefs HRR TSS
1	12.14	32.76	22.09	4.57	921	4.83	223.19	353.70
2	12.14	32.76	22.09	4.57	921	4.83	223.19	353.70
3	24.28	65.51	44.19	9.14	921	9.66	446.30	707.29
4	18.21	98.26	66.28	13.71	921	14.49	669.57	1061.09
5	60.7	131.02	118.06	24.43	921	25.82	1115.96	1768.48
6	109.26	274.51	185.13	38.31	921	40.49	1870.12	2963.65
7	109.26	294.87	198.86	41.15	921	43.49	2008.72	3183.26
8	109.26	294.87	198.86	41.15	921	43.49	2008.72	3183.26
9	60.7	131.02	118.06	24.43	921	25.82	1115.96	1768.48
10	36.42	98.26	66.28	13.71	921	14.49	669.57	1061.09
11	24.48	65.51	44.19	9.14	921	9.66	446.30	774.06
12	24.48	32.76	22.09	4.57	921	4.83	223.19	353.70
	601.33	**1552.09**	**1106.18**	**228.85**	**11052**	**241.89**	**11020.79**	**17531.71**
		129.34		19.07		20.16		

Notes: All secondary production numbers are in ash free dry weight and in kilograms/acre of habitat per month
All TSS reduction numbers are in kilograms TSS removed/acre/month

From the literature, I believe a reasonable figure would be a 10% trophic level transfer from primary to secondary level and that there is 1% chlorophyll A per unit weight of plankton, for modeling purposes.
It is obvious that this type of secondary production will filter a lot of plankton.
I believe the dry weight conversion of phytoplankton often used is 10% of the wet weight.

If you have better numbers on the plankton, please let me know. I can also provide "wet weights" of the different secondary production elements if needed.

Table A-1 (con't).

Fish Reefs LRR Sec Prod	Fish Reefs HRR Sec Prod	Fish Reef Original Plan TSS (HRR)	Fish Reef Original Plan Sec Prod (HRR)	Fish Reef Original Plan TSS (LRR)	Fish Reef Original Plan Sec Prod (LRR)
35.22	57.41	552.65	89.71	446.60	72.50
35.22	57.41	552.65	89.71	446.60	72.50
71.70	114.83	1105.14	179.42	893.06	144.99
107.55	172.24	1657.95	269.13	1339.79	217.49
179.24	287.07	2763.24	448.55	2232.98	362.48
311.16	498.36	4630.70	778.69	3742.07	629.26
322.70	516.73	4973.84	807.39	4019.36	652.46
322.70	516.73	4973.84	807.39	4019.36	652.46
179.24	287.07	2763.24	448.55	2232.98	362.48
107.55	172.24	1657.95	269.13	1339.79	217.49
71.70	114.83	1209.46	179.42	977.37	144.99
35.22	57.41	552.65	89.71	446.60	72.50
1779.20	**2852.36**	**27393.30**	**4456.82**	**22136.52**	**3601.55**
	237.70				

FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDICES B - G

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION

VIRGINIA BEACH, VIRGINIA

U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510-1096

July 2013 modified February 2014

LYNNHAVEN RIVER BASIN ENVIRONMENTAL RESTORATION
VIRGINIA BEACH, VIRGINIA
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ECONOMICS APPENDIX

In order to make more informed decisions with regard to the development and eventual selection of the NER Plan, a cost effectiveness analysis and incremental cost analysis was conducted on the 1631 alternatives, in addition to the no action plan, that were carried forward for evaluation and comparison (see Attachment A to this appendix). As required by USACE Planning Guidance, these analyses were conducted utilizing annualized costs, annualized benefits, and the IWR-Planning Suite Software (version 1.0.11.0). Cost effectiveness analysis identifies the plan, or plans, that produce(s) the greatest level of environmental output for the least cost. The environmental outputs, however measured, in turn reflect the environmental benefits, such as biological diversity, fish and wildlife habitat, and nutrient cycling, provided by the plan or plans. Incremental cost analysis examines the changes in costs and the changes in environmental outputs for each additional increment of environmental output. The Best Buy Plans represent those plans that produce the greatest increases in environmental outputs for the least increases in cost.

DESCRIPTION OF COSTS

The costs for constructing the different alternatives, as discussed in the main report, were developed using the Micro-Computer Aided Cost Estimating System. These amounts represent total or fixed fee cost estimates, as detailed in Appendix A, and are a conceptual representation of the approximate order-of-magnitude costs associated with the design concepts described. These estimates were based upon representative unit costs for similar construction projects in the area. All costs used in this comparison between alternatives are in October 2010 (Fiscal Year 2011) price levels, with a 4-1/8-percent discount rate used in present value and annualized over a 50-year period of analysis with a base year of 2014. However, the recommended plan has been updated to October 2012 levels with a discount rate 3.75, as shown in the main report.

The costs for each alternative plan include the following: preconstruction, engineering and design (PED); real estate; construction and plantings; construction management; adaptive management; contingency; and annual monitoring.

PED would include such costs as field surveys and investigations; design; preparation of specifications and construction drawings; and the development, approval, and execution of the project partnership agreement. The PED costs for the wetland sites were estimated to be 12 percent of construction costs, while the PED costs for Fish House Island were 8 percent, and those for reef habitat, SAV, and scallops were estimated at 6 percent of construction costs.

Real estate costs cover lands, easements, and rights-of-way, (LER's). The real estate costs for the Lynnhaven River Basin Restoration study include private lands for the wetland sites oyster leased area within the reef habitat, SAV, and scallop sites. Real estate assumptions and estimates have been updated since this analysis and are defined in more detail in the Real Estate Appendix.

Construction management costs cover the contractor's management, supervision, and overhead. These costs were 14 percent of the total construction costs for wetland sites, 7 percent for Fish House Island, and 4 percent for reef habitat, SAV, and scallop sites.

Adaptive management (AM) costs are included in the construction costs for each of the alternatives. The AM costs for each of the measures are estimated at 10 percent of total project costs based on the following. AM of hard reefs could range from 2 percent of construction costs, if removing collected sediments from the structures is required, to 10 percent of construction costs. For SAV, adaptive management could range from 2 percent of initial seeding costs, for signage to prevent wake zones, to 5 percent, in order to seed adjacent areas, and up to 10 percent, for reseeding of areas that did not establish as expected. While AM for reintroduction of scallops could range from 5 percent of initial seeding costs, if fencing is used to prevent predation or if spat collection is required, to 10 percent, in order to restock scallops in conjunction with the predation prevention measures. The AM plan for the wetland sites includes, if conditions require, the annual application of herbicides to control the growth and spread of *P. australis* and the annual replacement of native plantings for the first ten years of the project. Activities necessary to maintain the integrity of the habitat features constructed at the wetland sites, which include physical alterations of the marsh, will be planned as needed every five years.

A contingency cost was also added to PED, construction, and construction management costs to reflect the effects of unforeseen conditions on estimates of these costs. These costs do not allow for inflation or for omissions of work items that are known to be required; rather, they take into account any unforeseen construction problems. A 15 percent contingency was added to wetland, island, and reef habitat sites. A 25 percent contingency was added to SAV sites. And, a 30 percent contingency was added to scallop sites. The higher contingencies used for the SAV and scallop sites are due to the increased risk of success and need for possible reseeding or stocking of these habitats.

After the total costs were determined, the cost of interest during project construction was calculated based on various periods of construction for each of the project measures and a 4-1/8-percent discount rate. The total costs plus the costs of the interest during construction yield the investment cost, as seen in the following table.

Table B-1. INVESTMENT COSTS OF MEASURES

Measure/ Site	First Cost ($)	Interest during construction ($)	Investment Cost
Wetlands Creation:			
Narrows to Rainy Gut	326,000	6,000	332,000
Lake Windsor	436,000	4,000	440,000
Fish House Island Large	4,305,000	81,000	4,386,000
Fish House Island Medium	3,315,000	62,000	3,377,000
Fish House Island Small	2,067,000	39,000	2,106,000
Wetlands with Phragmites Eradication:			
Princess Anne High School	908,000	8,000	916,000
Mill Dam Creek	38,000	500	39,000
Great Neck North	349,000	3,000	352,000
Great Neck South	333,000	3,000	336,000
Reef Habitat:			
Lynnhaven Bay and Broad Bay (normal and soft foundation)	21,725,000	134,000	21,859,000
Lynnhaven Bay and Broad Bay (normal foundation)	11,990,000	85,000	12,075,000
Broad Bay (normal and soft)	14,731,000	75,000	14,806,000
Lynnhaven Bay	6,994,000	59,000	7,053,000
Broad Bay (normal foundation)	4,996,000	25,000	5,022,000
Submerged Aquatic Vegetation:			
Suitable Main Stem/Suitable Broad Bay	3,016,000	26,000	3,041,000
Suitable Main Stem/Key Broad Bay	2,369,000	12,000	2,381,000
Key Main Stem/Suitable Broad Bay	1,767,000	9,000	1,776,000
Suitable Broad Bay	1,578,000	3,000	1,581,000
Key Main Stem/Key Broad Bay	883,000	2,000	885,000
Key Broad Bay	664,000	0	664,000
Scallops:			
Suitable Main Stem/Suitable Broad Bay	1,439,000	12,000	1,451,000
Suitable Main Stem/Key Broad Bay	1,165,000	6,000	1,171,000
Key Main Stem/Suitable Broad Bay	887,000	4,000	891,000
Suitable Broad Bay	793,000	1,000	794,000
Key Main Stem/Key Broad Bay	442,000	1,000	443,000
Key Broad Bay	327,000	0	327,000
No action plan	0	0	N/A

Monitoring Costs

Annual monitoring will be conducted for each of the measures to ensure that project objectives are being fulfilled. The cost associated with monitoring reef habitat is estimated to be $40,000 annually for the first 10 years of the project, and $10,000 per year for the remainder of the 50-year period of analysis. For SAV, the cost of monitoring is also estimated to be $40,000 per year for the first five years of the project. After this period, no money has been allocated for SAV monitoring because it is anticipated that the project areas will be incorporated into the annual SAV monitoring program conducted by VIMS. Monitoring cost included for scallop reintroduction is $50,000 annually for the first five years of the project and $15,000 per year for the remainder of the 50-year period of analysis. Annual costs of $7,600 over the first 10 years of the project, and $3,800 thereafter, are estimated to be the monitoring cost associated with the wetland sites. These estimated monitoring costs are for the combined maximum acreage of each measure at all sites. The estimated monitoring costs for individual sites in Table B-2 were pro-rated based on acreage.

Maintenance Costs

After the ten year adaptive management term is complete, it is anticipated the application of herbicides to control the growth and spread of *P. australis* will continue to be necessary every five years for the life of the project. The cost of each herbicide application is estimated to be $1,000 for each wetlands site. This cost is included in the average annual costs as subsequently discussed.

Average Annual Costs

Using the total investment costs and annual monitoring, the average annual equivalent costs were derived for each alternative plan, based on a 50-year period of analysis, a 4-1/8-percent discount rate, and October 2010 (FY 2011) price levels. The interest and amortization, average annual monitoring costs, and total average annual costs for the measures included in the alternatives carried forward for evaluation can be found in the following table.

Table B-2. AVERAGE ANNUAL COSTS OF MEASURES

Measure/ Site	Interest and amortization ($)	Average annual monitoring and maintenance ($)	Total average annual costs ($)
Wetlands Creation:			
Narrows to Rainy Gut	15,800	100	15,900
Lake Windsor	20,900	100	21,000
Fish House Island Large	208,500	600	209,100
Fish House Island Medium	160,600	400	161,000
Fish House Island Small	100,100	200	100,300
Wetlands Restoration/Diversitfication:			
Princess Anne High School	43,600	1,000	44,600
Mill Dam Creek	1,800	600	2,400
Great Neck North	16,700	3,200	19,900
Great Neck South	16,000	2,300	18,300
Reef Habitat:			
Lynnhaven Bay and Broad Bay (normal and soft foundation)	1,011,700	20,900	1,032,600
Lynnhaven Bay and Broad Bay (normal foundation)	564,800	13,900	578,700
Broad Bay (normal and soft)	676,300	13,700	690,000
Lynnhaven Bay	335,400	7,300	342,700
Broad Bay (normal foundation)	229,400	6,600	236,000
Submerged Aquatic Vegetation:			
Suitable Main Stem/Suitable Broad Bay	138,900	8,100	147,000
Suitable Main Stem/Key Broad Bay	108,700	5,900	114,600
Key Main Stem/Suitable Broad Bay	81,100	4,100	85,200
Suitable Broad Bay	72,200	3,600	75,800
Key Main Stem/Key Broad Bay	40,400	1,900	42,300
Key Broad Bay	30,300	1,400	31,700
Scallops:			
Suitable Main Stem/Suitable Broad Bay	63,700	20,500	84,200
Suitable Main Stem/Key Broad Bay	51,400	14,800	66,100
Key Main Stem/Suitable Broad Bay	39,100	10,400	49,500
Suitable Broad Bay	34,800	9,100	44,000
Key Main Stem/Key Broad Bay	19,400	4,700	24,200
Key Broad Bay	14,300	3,400	17,700
No action plan	0	0	N/A

DESCRIPTION OF ENVIRONMENTAL BENEFITS

Three environmental parameters were estimated for each of the measures related to SAV reseeding, reef habitat construction, bay scallops reintroduction, and the construction of tidal wetlands, as well as the corresponding without project conditions. These parameters were: secondary production, species diversity through a benthic index of biotic integrity (BIBI), and reduction of total suspended solids. Environmental benefits were estimated for measures related to the restoration of existing wetlands and the eradication of *Phragmites* using habitat diversity, which will described later in this section.

In order to assess whether greater importance should be given to any of these three parameters, a sensitivity analysis was completed. The sensitivity analysis demonstrated that if TSS is removed from consideration the conclusions of the original cost/benefit analysis are similar to when it is included. This is consistent with the fact that although water quality is important to habitat, it is not a direct measurement of habitat improvement. Therefore, only secondary production and species diversity were quantitatively used in plan selection for this project. The estimates for the parameters can be found in the following table. Details on how these numbers were calculated, can be found in Appendix C, Ecological Benefits

Table B-3. ANNUAL ESTIMATED BENEFITS PER ACRE FOR EACH PROJECT MEASURE

Measure	Secondary Production (kg/acre/yr)	BIBI (1-5)
Wetland creation	242	4
SAV	1,552	5
Scallops	229	3.5
Reef habitat high relief	4,457	5
Reef habitat low relief	3,601	5
Existing Condition/ Without Project	6.41	3

For each of the parameters, the estimates for the without project condition were subtracted from the output estimated for each of the measures to determine the net benefit associated with each measure. The estimates were then multiplied by the acreage for each specific site/scale for each measure to determine the total output for each specific site/scale of each measure. It is assumed that each of the estimated outputs is additive when specific measures are combined into the various alternatives, with no significant magnified effect from various measures being built together. Thus, the parameter output estimates for the appropriate measures were added together to determine the total benefits for each of the various alternatives. Secondary production benefits are calculated as average annual kg per acre, and BIBI benefits are calculated as an average annual index (1-5 scale per acre).

It was assumed each of the measures would take various amounts of time after construction to achieve the full level of estimated benefits. The time for each measure to attain its full environmental potential and appropriate growth rates, as determined by literature research, was applied to each of the measures over a 50-year period of analysis. A linear growth rate was assumed for the wetlands, reef habitat, SAV, and scallops with the same acreage as SAV. An exponential growth rate was assumed for the minimum amount of scallops when combined with the maximum amount of SAV for a given area. It is believed that the existing without project condition would stay relatively steady over the 50-year period of analysis, so the average annual outputs were assumed to be constant.

The average annual benefits for each alternative were derived by multiplying each of the parameter's annual output for each measure by the estimated percentage of output for each year of the 50-year period of analysis. The results for each year of the period of analysis were then averaged to determine the average annual benefit attributable to each scale of each measure for each of the parameters. The benefits for the appropriate measures were then summed to derive the average annual benefit for each of the parameters to determine the average annual benefits for each alternative. The average annual benefits for each measure can be seen in the following table.

Table B-4. AVERAGE ANNUAL BENEFITS

Measure/Site	Secondary Production (kg)	BIBI (Index Score)
WETLAND CREATION		
Narrows to Rainy Gut	29	0.18
Lake Windsor	39	0.24
Fish House Island : large	6456	8.50
Fish House Island: medium	4799	5.52
Fish House Island: small	3641	3.22
REEF HABITAT		
Lynnhaven Bay and Broad Bay (normal and soft foundation)	124185	60.75
Lynnhaven Bay and Broad Bay (normal foundation)	79068	40.15
Broad Bay (normal and soft foundation)	87681	40.04
Lynnhaven Bay	36504	20.71
Broad Bay (normal foundation)	42565	19.44
SUBMERGED AQUATIC VEG		
Suitable Areas Main Stem/Suitable Areas Broad Bay	141158	181.89
Suitable Areas Main Stem/ Key Areas Broad Bay	101984	131.42
Key Areas Main Stem/Suitable Areas Broad Bay	71677	92.36
Suitable Areas Broad Bay	62705	80.80
Key Areas Main Stem/ Key Areas Broad Bay	32502	41.88
Key Areas Broad Bay	23531	30.32
SCALLOPS		
Suitable Areas Main Stem/ Suitable Areas Broad Bay	20384	44.54
Key Areas Main Stem/ Key Areas Broad Bay	19579	42.78
Suitable Areas Main Stem/Key Areas Broad Bay	14727	32.18
Key Areas Main Stem/ Key Areas Broad Bay (with Suitable Areas SAV in Main Stem)	14279	31.20
Key Areas Main Stem/Suitable Areas Broad Bay	10351	22.61
Key Areas Main Stem/Key Areas Broad Bay (with Suitable Areas SAV in Broad Bay)	9993	21.93
Suitable Areas Broad Bay	9055	19.78
Key Areas Broad Bay (with Suitable Areas SAV)	8697	19
Key Areas Broad Bay/Key Areas Main Stem	4694	10.25
Key Areas Broad Bay	3398	7.42
No Action Plan	0	0

Wetland Restoration/Diversification Sites

The parameters used to assess benefits gained through the implementation of the other restoration measures are not able to adequately capture environmental improvements produced through the modification of the four wetland sites. Instead, the environmental benefits gained through the restoration/diversification of the wetland sites (Princess Anne, Great Neck North, Great Neck South, and Mill Dam Creek) were determined using a model developed by the USEPA. The model quantifies wildlife habitat value of "salt marshes based on marsh characteristics and the presence of habitat types that influence habitat used by terrestrial wildlife." The model and the application of the model to the Lynnhaven River Basin Restoration Project have been described in detail in Appendix C. The average annual benefits calculated using the EPA model can be found in the following table for each of the wetland restoration sites. The spreadsheets which include the individual component values for each site are included in the Environmental Appendix.

Table B-5. WETLANDS WITH PHRAGMITES ERADICATION SITES AVERAGE ANNUAL BENEFITS

Wetlands with *Phragmites* Eradication Site	Net Average Annual WetlandBenefits (With Project – Without Project Condition) (Assessment score on a 784-point scale)*
Princess Anne High School	85
Mill Dam Creek	66
Great Neck North	52
Great Neck South	75
No Action Plan	0

*Severely impaired marshes can receive scores below 100; while reference sites, which are high quality and relatively unimpaired, in the Lynnhaven River Basin received scores up to 552.

COST EFFECTIVE AND INCREMENTAL COST ANALYIS

The average annual costs and average annual benefits identified previously were used to conduct cost effectiveness and incremental cost analyses, using IWR Planning Suite version 1.0.11.0. For the CE/ICA, the following naming convention was used to indicate the measures included in each of the alternatives being analyzed.

Table B-6. FINAL ARRAY OF MEASURES COMBINED INTO ALTERNATIVES

Measure and Site/Scale	IWR Planning Suite Plan Code
Fish House Island (Wetland Creation) – 1 site, 3 scales	
Large Island	ISL1
Medium Island	ISL2
Small Island	ISL3
Reef Habitat – 2 sites, 5 scales	
Lynnhaven Bay and Broad Bay (normal and soft bottom)	RH1
Lynnhaven Bay and Broad Bay (normal bottom)	RH2
Broad Bay (normal and soft bottom)	RH3
Lynnhaven Bay	RH4
Broad Bay (normal bottom)	RH5
Submerged Aquatic Vegetation – 2 sites, 6 scales	
Suitable Main Stem/Suitable Broad Bay	SAV1,2,3
Key Main Stem/Suitable Broad Bay	SAV4,5,6
Suitable Main Stem/Key Broad Bay	SAV7,8,9
Suitable Broad Bay	SAV10,11,12
Key Main Stem/Key Broad Bay	SAV13,14
Key Broad Bay	SAV15,16
Scallops – 2 sites, 10 scales	
Suitable Main Stem/Suitable Broad Bay	SCL1
Key Main Stem (with Suitable SAV in Main Stem)/ Key Broad Bay (with Suitable SAV in Broad Bay)	SCL2
Key Main Stem/Suitable Broad Bay	SCL4
Key Main Stem/Key Broad Bay (with Suitable SAV in Broad Bay)	SCL5
Suitable Main Stem/Key Broad Bay	SCL7
Key Main Stem (with Suitable SAV)/Key Broad Bay	SCL8

Table B-6. FINAL ARRAY OF MEASURES COMBINED INTO ALTERNATIVES (Cont'd)

Measure and Site/Scale	IWR Planning Suite Plan Code
Suitable Broad Bay	SCL10
Key Broad Bay (with Suitable SAV in Broad Bay)	SCL11
Key Main Stem/Key Broad Bay	SCL13
Key Broad Bay	SCL15
Wetland Creation – 2 sites	
Narrows to Rainy Gut	NR
Lake Windsor	LW
Wetlands Restoration/Diversification – 4 sites	
Princess Anne High School (wetland restoration)	PA
South Great Neck (wetland restoration/diversification)	SG
Mill Dam Neck (wetland restoration/diversification)	MD
North Great Neck (wetland restoration)	NG

Multivariable Analysis

The average annual costs and average annual benefits identified previously were used to conduct cost effectiveness and incremental cost analyses for the 1631 alternative plans, as discussed previously, as well as the No Action Plan. In the case of alternative plans that include measures related to SAV, reef habitat, scallops, and wetland creation, three separate parameter outputs were initially used to indicate the environmental benefit associated with each of the alternatives under consideration.

Sensitivity Analysis on Weighting of Parameters

The original cost/benefits analysis was completed using three environmental parameters: secondary production, species diversity, and TSS. In order to assess the effect on the outcome of the CE/ICA if greater importance was given to any of the three original benefit parameters (shown in detail in subsequently in this Appendix) was performed to evaluate the effect of various weights on the results of the analysis. The analysis was rerun with the following weights;

- 50 percent TSS reduction, 50 percent secondary production, 0 percent BIBI
- 0 percent TSS reduction, 50 percent secondary production, 50 percent BIBI
- 50 percent TSS reduction, 0 percent secondary production, 50 percent BIBI
- 100 percent weight on TSS reduction
- 100 percent weight on Secondary Production
- 100 percent weight on the BIBI.

TABLE B-7. DESCRIPTION OF BEST BUY ALTERNATIVES

Alternative	SAV	Scallops	Reef Habitat	Wetland Creation
A	Suitable Areas in Main Stem and Broad Bay	Key Areas in Main Stem and Broad Bay	None	None
B	Suitable Areas in Main Stem and Broad ay	Key areas in Main Stem and Broad Bay	Broad Bay on normal foundation	None
C	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal foundation	None
D	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	None
E	Suitable Area SAV in Main Stem and Broad Bay	Key Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design)
F	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design)
G	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design), and Lake Windsor
H	Suitable Area SAV in Main Stem and Broad Bay	Sustainable Areas Scallops in Main Stem and Broad Bay	Lynnhaven Bay and Broad Bay on normal and soft foundation	Fish House Island (Large Design), Lake Windsor, Narrows to Rainy Gut

Table B-8. SUMMARY OF SENSITIVITY ANALYSIS ON WEIGHTING (BEST BUY PLANS)

Best Buy Plans	Equal Weights (Main Analysis)	100% TSS	100% SP	100% BIBI	50% TSS/50%SP	50%TSS/50%BIBI	50%SP/50%BIBI
A	x		x	x	x	x	x
B	x	x	x	x	x	x	x
C	x	x	x	x	x	x	x
D	x	x	x	x	x	x	x
E	x	x	x	x	x	x	x
F**	x		x	x	x	x	x
G**	x		x	x	x	x	x
H**	x	x	x	x	x	x	x
I*			x				
J*		x					
K*			x				
L*		x					
M*		x					

*Plans not carried forward for consideration because only identified as best buy plan by one of the sensitivity analyses and not by the main CE/ICA.
**Plan not carried forward for consideration because of very high incremental costs

It was specifically identified through the analysis, using only secondary production and species diversity (0 percent weight on TSS reduction, 50 percent weight on secondary production, and 50 percent weight on BIBI), that the resulting best buy plans are the same when the benefits are analyzed with or without the TSS reduction parameter. This is because the MCDA scores, though different with and without inclusion of the TSS parameter, follow the same positively increasing pattern in output associated with each alternative plan under consideration. Therefore, as the TSS is not necessary for differentiating plans, and as it more of an indicator of water quality rather than a measurement of habitat improvement, it was not used in identification of the NER Plan.

Multi Criteria Decision Analysis

In the case of alternative plans that include measures related to SAV, reef habitat, scallops, and wetland creation, it was determined that more than one parameter output would best indicate the environmental benefit associated with each of the alternatives under consideration. The CE/ICA for plans that include wetland restoration measures is described in the following section.

Typically, CE/ICA is conducted on one benefit output and one cost output. Therefore, the CE/ICA analysis for this study was not as straightforward as with other studies. The Multi-Criteria Decision Analysis Module (MCDA) of IWR-Planning Suite was used as a means to combine the three parameters into one benefit metric to compare with costs in CE/ICA.

The MCDA Module of IWR-Planning Suite provides a numerical method for comparing benefit parameters with inconsistent units. The benefit values entered into the MCDA are evaluated as a matrix, with each row being an alternative and each column a benefit category. All of the values in the matrix are normalized and ranked to determine a single score for each alternative (or row) under evaluation. For this evaluation, the values were ranked using the weighted scoring ranking method and normalized using the normalization to range method. (U.S. Army Corps of Engineers Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010)

Ranking Method

Ranking methodology aims to find the relative minimum and maximum of each benefit category for all of the rows in a matrix (or planning set) in order to rank the rows from the optimal solution to the least optimal solution. There are several ranking methods available for use in the MCDA module: weighted scoring, compromise programming, and outranking. The weighted scoring technique, the ranking method used for this analysis, compares plans to one another and assumes higher benefit values result in a more beneficial plan. This particular ranking method was chosen for use due to its lack of complexity as compared to the other ranking methods. Weighted scoring of a planning set is performed as follows: values are normalized; values for maximized categories are multiplied by designated weights; weights for minimized categories are converted to negative and then multiplied by the criterion (benefit value); raw weighted values for alternatives are generated by adding together the score values for a particular row; these scores are then normalized once again to generate scores that fall between 0 and 1. (U.S. Army Corps of Engineers Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010)

Normalization Method

Normalization allows benefit categories with different units of measurement to be evaluated together in one analysis. The weighted scoring ranking method allows for use of three different normalization methods: normalization to maximum, normalization to range, and normalization to percent of total. The normalization to range method was chosen for this evaluation since this method assures that the values of zero and one will be included in the results; whereas, the other normalization methods do not guarantee this. In this study, a minimum raw value of zero was used in all instances for the No Action plan. So, the results of this normalization method are no different than would be found with the use of the normalization to maximum method. With the normalization by range method, the normalized value is calculated as follows:
$v = (a - \min a) / (\max a - \min a)$, where a = "raw" value of criterion. (U.S. Army Corps of Engineers Institute for Water Resources, IWR Planning Suite MCDA Module User's Guide, October 2010)

Weighting of Values

As discussed previously, MCDA allows for the use of weights to reflect the importance of each parameter under evaluation. The sensitivity analysis performed confirmed the assumption that none of the parameters have a significantly greater bearing on the overall value of the system. Due to this, and their joint, central importance to the ecological benefits model, it was decided to weight them equally.

Additionally, the Chesapeake Bay Program has also recently been given more attention by the current administration. EO 13508, Chesapeake Bay Protection and Restoration, outlines a strategy to improve the water quality, restore and protect watershed habitat, sub-aqueous habitat, and organisms that live in it. The selected parameters aid in meeting goals outlined in the Action Plan associated with EO 13508.

Example Score Calculations

A score for each alternative was calculated using the weighted scoring method andn normalized using the normalization to range method as discussed previously. The following is an example of how these scores were calculated within the MCDA module.

Plan NR0LW0ISL0SAVSCL14EFH2 average annual benefits:
TSS = 508181; SP = 111571; BIBI = 82

Values are normalized as follows:
Normalized TSS = (508181 – 0) / (1036344 – 0) = 0.49
Normalized SP = (111571 – 0) / (292235 – 0) = 0.38
Normalized BIBI = (82 – 0) / (296.10 – 0) = 0.28

Normalized values are multiplied by weight (equal weights int his case):
Weighted TSS = 0.49 * 1/3 = 0.16
Weighted SP = 0.38 * 1/3 = 0.13
Weighted BIBI = 0.28 * 1/3 = 0.09

Weighted values are summed:
Score = 0.16 + 0.13 + 0.09 = 0.38

Score is normalized again:
Nomalized Score = (0.38 – 0) / (1 – 0) = 0.38

Cost Effectiveness and Incremental Cost Analysis on MCDA Scores

A cost effectiveness and incremental cost analysis was conducted on the scores derived using the MCDA weighted scoring method with equal weighting, as discussed previously. The results of the cost effectiveness analysis using the MCDA weighted scoring method indicated 124 of the considered plans to be cost effective. The cost-effective plans can be found in the following table. Each of these plans is the least-costly means of providing the associated level of output or benefit.

Table B-9. RESULTS OF MCDA WEIGHTED SCORING COST EFFECTIVENESS ANALYSIS

Alternative Plan	Score	Cost ($)	Average Cost ($)
No Action Plan	0.00	0.00	
NR1LW0ISL0SAVSCL0RH0	0.00	16,000	18,308,000
NR0LW1ISL0SAVSCL0RH0	0.00	21,000	18,182,000
NR0LW0ISL0SAVSCL16RH0	0.06	32,000	496,000
NR0LW0ISL0SAVSCL14RH0	0.09	42,000	479,000
NR1LW0ISL0SAVSCL14RH0	0.09	58,000	652,000
NR0LW1ISL0SAVSCL14RH0	0.09	63,000	707,000
NR0LW0ISL0SAVSCL13RH0	0.11	66,000	590,000
NR0LW0ISL0SAVSCL12RH0	0.17	76,000	445,000
NR0LW0ISL0SAVSCL6RH0	0.19	85,000	438,000
NR0LW0ISL0SAVSCL11RH0	0.22	94,000	435,000
NR0LW0ISL0SAVSCL5RH0	0.25	109,000	444,000
NR0LW0ISL0SAVSCL9RH0	0.28	115000	414,000
NR1LW0ISL0SAVSCL9RH0	0.28	130,000	469,000
NR0LW1ISL0SAVSCL9RH0	0.28	136,000	487,000
NR0LW0ISL0SAVSCL8RH0	0.35	139,000	396,000
NR0LW0ISL0SAVSCL3RH0	0.38	147,000	383,000
NR1LW0ISL0SAVSCL3RH0	0.38	163,000	424,000
NR0LW1ISL0SAVSCL3RH0	0.38	168,000	437,000
NR0LW0ISL0SAVSCL2RH0	0.48	171,000	353,000
NR1LW0ISL0SAVSCL2RH0	0.49	187,000	385,000
NR0LW1ISL0SAVSCL2RH0	0.49	192,000	396,000
NR1LW1ISL0SAVSCL2RH0	0.49	208,000	428,000
NR0LW0ISL0SAVSCL1RH0	0.49	231,000	473,000
NR1LW0ISL0SAVSCL1RH0	0.49	247,000	505,000
NR0LW1ISL0SAVSCL1RH0	0.49	252,000	515,000
NR1LW1ISL0SAVSCL1RH0	0.49	268,000	546,000

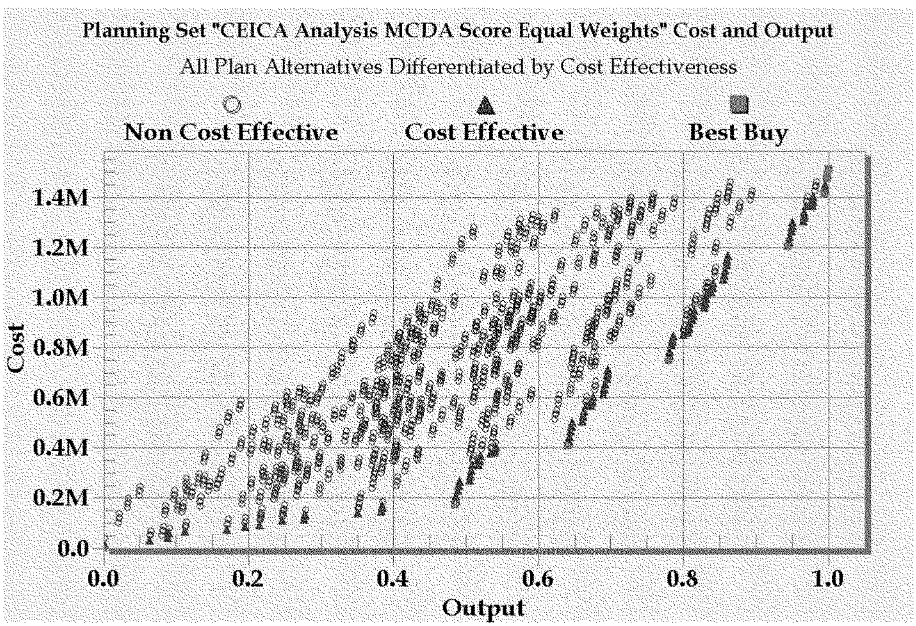
NR0LW0ISL3SAVSCL2RH0	0.50	272,000	538,000
NR1LW0ISL3SAVSCL2RH0	0.51	287,000	568,000
NR0LW1ISL3SAVSCL2RH0	0.51	293,000	578,000
NR1LW1ISL3SAVSCL2RH0	0.51	308,000	608,000
NR0LW0ISL3SAVSCL1RH0	0.51	332,000	651,000
NR0LW0ISL2SAVSCL2RH0	0.52	332,000	642,000
NR1LW0ISL2SAVSCL2RH0	0.52	348,000	672,000
NR0LW1ISL2SAVSCL2RH0	0.52	353,000	681,000
NR1LW1ISL2SAVSCL2RH0	0.52	369,000	710,000
NR0LW0ISL1SAVSCL2RH0	0.53	380,000	713,000
NR0LW0ISL0SAVSCL3RH5	0.54	383,000	710,000
NR1LW0ISL0SAVSCL3RH5	0.54	390,000	738,000
NR0LW1ISL0SAVSCL3RH5	0.54	404,000	747,000
NR0LW0ISL0SAVSCL2RH5	0.64	407,000	636,000
NR1LW0ISL0SAVSCL2RH5	0.64	423,000	660,000
NR0LW1ISL0SAVSCL2RH5	0.64	428,000	667,000
NR1LW1ISL0SAVSCL2RH5	0.64	444,000	691,000
NR0LW0ISL0SAVSCL1RH5	0.64	467,000	725,000
NR1LW0ISL0SAVSCL1RH5	0.65	483,000	748,000
NR0LW1ISL0SAVSCL1RH5	0.65	488,000	756,000
NR1LW1ISL0SAVSCL1RH5	0.65	504,000	779,000
NR0LW0ISL3SAVSCL2RH5	0.66	508,000	768,000
NR1LW0ISL3SAVSCL2RH5	0.66	523,000	791,000
NR0LW1ISL3SAVSCL2RH5	0.66	529,000	798,000
NR1LW1ISL3SAVSCL2RH5	0.66	544,000	821,000
NR0LW0ISL3SAVSCL1RH5	0.67	568,000	853,000
NR0LW0ISL2SAVSCL2RH5	0.67	568,000	844,000
NR1LW0ISL2SAVSCL2RH5	0.67	584,000	866,000
NR0LW1ISL2SAVSCL2RH5	0.67	589,000	873,000
NR1LW1ISL2SAVSCL2RH5	0.68	605,000	896,000
NR0LW0ISL1SAVSCL2RH5	0.69	616,000	893,000
NR1LW0ISL1SAVSCL2RH5	0.69	632,000	915,000
NR0LW1ISL1SAVSCL2RH5	0.69	637,000	922,000
NR1LW1ISL1SAVSCL2RH5	0.69	653,000	944,000
NR0LW0ISL1SAVSCL1RH5	0.69	676,000	975,000
NR1LW0ISL1SAVSCL1RH5	0.69	692,000	996,000
NR0LW1ISL1SAVSCL1RH5	0.70	697,000	1,003,000
NR1LW1ISL1SAVSCL1RH5	0.70	713,000	1,025,000
NR0LW0ISL0SAVSCL2RH2	0.78	750,000	962,000
NR1LW0ISL0SAVSCL2RH2	0.78	766,000	982,000
NR0LW1ISL0SAVSCL2RH2	0.78	771,000	988,000
NR1LW1ISL0SAVSCL2RH2	0.78	787,000	1,007,000
NR0LW0ISL0SAVSCL1RH2	0.78	810,000	1,034,000
NR1LW0ISL0SAVSCL1RH2	0.78	826,000	1,053,000
NR0LW1ISL0SAVSCL1RH2	0.78	831,000	1,059,000
NR1LW1ISL0SAVSCL1RH2	0.79	847,000	1,078,000

NR0LW0ISL3SAVSCL2RH2	0.80	850,000	1,063,000
NR0LW0ISL0SAVSCL2RH3	0.81	861,000	1,069,000
NR1LW0ISL0SAVSCL2RH3	0.81	877,000	1,087,000
NR0LW1ISL0SAVSCL2RH3	0.81	882,000	1,093,000
NR1LW1ISL0SAVSCL2RH3	0.81	898,000	1,111,000
NR0LW0ISL2SAVSCL2RH2	0.81	911,000	1,121,000
NR1LW0ISL2SAVSCL2RH2	0.81	927,000	1,140,000
NR0LW1ISL2SAVSCL2RH2	0.81	932,000	1,146,000
NR1LW1ISL2SAVSCL2RH2	0.81	948,000	1,164,000
NR0LW0ISL1SAVSCL2RH2	0.83	959,000	1,158,000
NR1LW0ISL1SAVSCL2RH2	0.83	975,000	1,175,000
NR0LW1ISL1SAVSCL2RH2	0.83	980,000	1,181,000
NR1LW1ISL1SAVSCL2RH2	0.83	996,000	1,199,000
NR0LW0ISL1SAVSCL1RH2	0.83	1,019,000	1,224,000
NR0LW0ISL2SAVSCL2RH3	0.84	1,022,000	1,218,000
NR1LW0ISL2SAVSCL2RH3	0.84	1,038,000	1,236,000
NR0LW1ISL2SAVSCL2RH3	0.84	1,043,000	1,242,000
NR1LW1ISL2SAVSCL2RH3	0.84	1,059,000	1,259,000
NR0LW0ISL1SAVSCL2RH3	0.86	1,070,000	1,251,000
NR1LW0ISL1SAVSCL2RH3	0.86	1,086,000	1,269,000
NR0LW1ISL1SAVSCL2RH3	0.86	1,091,000	1,274,000
NR1LW1ISL1SAVSCL2RH3	0.86	1,107,000	1,292,000
NR0LW0ISL1SAVSCL1RH3	0.86	1,130,000	1,315,000
NR1LW0ISL1SAVSCL1RH3	0.86	1,146,000	1,332,000
NR0LW1ISL1SAVSCL1RH3	0.86	1,151,000	1,338,000
NR1LW1ISL1SAVSCL1RH3	0.86	1,167,000	1,355,000
NR0LW0ISL0SAVSCL2RH1	0.94	1,204,000	1,274,000
NR1LW0ISL0SAVSCL2RH1	0.95	1,220,000	1,290,000
NR0LW1ISL0SAVSCL2RH1	0.95	1,225,000	1,295,000
NR1LW1ISL0SAVSCL2RH1	0.95	1,241,000	1,311,000
NR0LW0ISL0SAVSCL1RH1	0.95	1,264,000	1,332,000
NR1LW0ISL0SAVSCL1RH1	0.95	1,280,000	1,348,000
NR0LW1ISL0SAVSCL1RH1	0.95	1,285,000	1,353,000
NR1LW1ISL0SAVSCL1RH1	0.95	1,301,000	1,368,000
NR0LW0ISL3SAVSCL2RH1	0.97	1,304,000	1,351,000
NR1LW0ISL3SAVSCL2RH1	0.97	1,320,000	1,367,000
NR0LW1ISL3SAVSCL2RH1	0.97	1,325,000	1,371,000
NR1LW1ISL3SAVSCL2RH1	0.97	1,341,000	1,387,000
NR0LW0ISL3SAVSCL1RH1	0.97	1,364,000	1,407,000
NR0LW0ISL2SAVSCL2RH1	0.98	1,365,000	1,396,000
NR1LW0ISL2SAVSCL2RH1	0.98	1,381,000	1,411,000
NR0LW1ISL2SAVSCL2RH1	0.98	1,386,000	1,416,000
NR1LW1ISL2SAVSCL2RH1	0.98	1,402,000	1,431,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,413,000	1,422,000
NR1LW0ISL1SAVSCL2RH1	0.99	1,429,000	1,436,000
NR0LW1ISL1SAVSCL2RH1	0.99	1,434,000	1,441,000

NR1LW1ISL1SAVSCL2RH1	1.00	1,450,000	1,456,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,476,000
NR1LW0ISL1SAVSCL1RH1	1.00	1,489,000	1,491,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,495,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000

Figure B-1 illustrates the cost-effective analysis results, showing average annual environmental benefits (horizontal axis) and average annual costs (vertical axis) of the 123 alternatives, as well as the No Action Plan, which is carried forward for comparison purposes only.

Figure B-1. MCDA WEIGHTED SCORING COST-EFFECTIVE PLANS

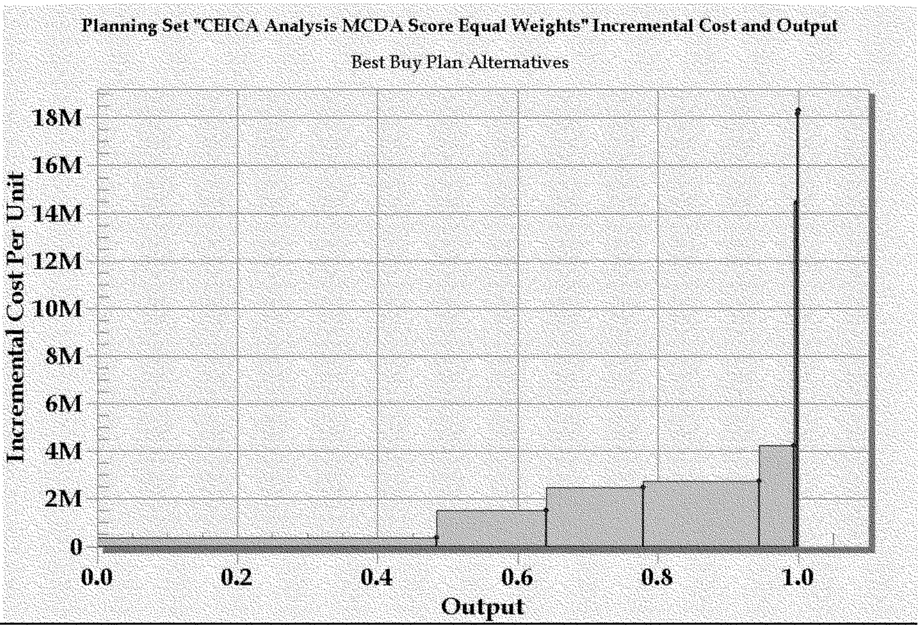


After conducting the cost effectiveness analysis, incremental cost analysis examines the changes in costs and changes in environmental benefits for each additional increment of output. For each best buy plan there are no other plans that will give the same level of output at a lower incremental cost. The plan with the lowest overall average cost per unit of output, advancing from the No Action Plan, is the first Best Buy Plan. After the first Best Buy Plan is identified, subsequent incremental analyses are done to calculate the change in costs and change in outputs of advancing from the first Best Buy Plan to all of the remaining (and larger) cost-effective plans. The results of the incremental cost analysis using the MCDA weighted scoring method indicated eight of the considered plans, in addition to the no action plan, to be best buy plans. The following table summarizes the information from the incremental cost analysis of the alternatives, and Figure 2 displays the information graphically.

Table B-10. RESULTS OF MCDA WEIGHTED SCORING INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.48	171,000	353,000	171,000	0.4845	353,000
NR0LW0ISL0SAVSCL2RH5	0.64	407,000	636,000	236,000	0.1561	1,512,000
NR0LW0ISL0SAVSCL2RH2	0.78	750,000	962,000	343,000	0.1387	2,471,000
NR0LW0ISL0SAVSCL2RH1	0.94	1,204,000	1,274,000	454,000	0.1654	2,745,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,413,000	1,422,000	209,000	0.0493	4,245,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,476,000	60,000	0.0042	14,449,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,495,000	21,000	0.0012	18,182,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	16,000	0.0009	18,308,000

Figure B-2. MCDA WEIGHTED SCORING BEST BUY PLANS



Sensitivity Analysis on Importance of Parameters

As discussed previously, a sensitivity anlaysis was conducted on the weights applied to each benefit parameter. For the main analysis it is assumed TSS reduction, secondary production, and the BIBI are of equal importance on the overall value of the system, thus equal weights were applied to the parameters. Because of the uncertainty associated with this assumption, the application of weights was varied to examine how the resulting cost effective and best buy plans are affected as compared to the use equal weights. In order to assess the effect on the outcome of the CE/ICA, should greater importance be given to any of the three benefit parameters used in the analysis, the analysis was rerun with the following weights;

- 50 percent TSS reduction, 50 percent secondary production, 0 percent BIBI
- 0 percent TSS reduction, 50 percent secondary production, 50 percent BIBI
- 50 percent TSS reduction, 0 percent secondary production, 50 percent BIBI
- 100 percent weight on TSS reduction
- 100 percent weight on Secondary Production
- 100 percent weight on the BIBI.

The majority of the results of the sensitivity analysis on weighting supported the same best buy plans as those identified by the incremental cost analysis using the MCDA scores derived with equal weights on each parameter. There were several additional best buy plans identified by the analysis with varying weights, however these best buy plans were either less or greater in terms of output than those plans identified by the main analysis.

The results of the incremental cost analyses for each of the aforementioned weighting scenarios are presented in the following tables.

Table B-11. RESULTS OF 50 PERCENT IMPORTANCE ON TSS REDUCTION AND SECONDARY PRODUCTION INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.35	171,000	493,000	171,000	0.3473	493,000
NR0LW0ISL0SAVSCL2RH5	0.55	407,000	742,000	236,000	0.2013	1,173,000
NR0LW0ISL0SAVSCL2RH2	0.72	750,000	1,039,000	343,000	0.1731	1,980,000
NR0LW0ISL0SAVSCL2RH1	0.93	1,204,000	1,288,000	454,000	0.2133	2,129,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,413,000	1,421,000	209,000	0.0595	3,512,000
NR0LW1ISL1SAVSCL2RH1	1.00	1,434,000	1,440,000	21,000	0.0013	15,827,000
NR1LW1ISL1SAVSCL2RH1	1.00	1,450,000	1,455,000	16,000	0.0010	15,925,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,5110,000	1,510,000	60,000	0.0033	18,422,000

Table B-12. RESULTS OF 50 PERCENT IMPORTANCE ON SECONDARY PRODUCTION AND BIBI INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.65	171,000	262,000	171,000	0.6544	262,000
NR0LW0ISL0SAVSCL2RH5	0.76	407,000	536,000	236,000	0.1057	2,234,000
NR0LW0ISL0SAVSCL2RH2	0.86	750,000	874,000	343,000	0.0974	3,517,000
NR0LW0ISL0SAVSCL2RH1	0.97	1,204,000	1,242,000	454,000	0.1119	4,055,000
NR0LW0ISL1SAVSCL2R1	0.99	1,413,000	1,420,000	209,000	0.0254	8,233,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,474,000	60,000	0.0044	13,792,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,494,000	21,000	0.0005	44,465,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	16,000	0.0004	44,846,000

Table B-13. RESULTS OF 50 PERCENT IMPORTANCE ON TSS REDUCTION AND BIBI INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.45	171,000	379,000	171,000	0.4517	379,000
NR0LW0ISL0SAVSCL2RH5	0.61	407,000	664,000	236,000	0.1613	1,463,000
NR0LW0ISL0SAVSCL2RH2	0.76	750,000	989,000	343,000	0.1456	2,354,000
NR0LW0ISL0SAVSCL2RH1	0.93	1,204,000	1,295,000	454,000	0.1709	2,657,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,413,000	1,424,000	209,000	0.0628	3,328,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,477,000	60,000	0.0049	12,370,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,496,000	21,000	0.0017	12,607,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	16,000	0.0013	12,694,000

Table B-14. RESULTS OF 100 PERCENT IMPORTANCE ON TSS REDUCTION INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL0RH5	0.26	236,000	919,000	236,000	0.2569	919,000
NR0LW0ISL0SAVSCL2RH5	0.40	407,000	1,014,000	171,000	0.1446	1,184,000
NR0LW0ISL0SAVSCL2RH2	0.62	750,000	1,204,00	343,000	0.2212	1,549,000
NR0LW0ISL0SAVSCL2RH1	0.89	1,204,000	1,345,000	454,000	0.2722	1,668,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,412,000	1,425,000	209,000	0.0970	2,156,000
NR0LW1ISL1SAVSCL2RH1	0.99	1,434,000	1,442,000	21,000	0.0025	8,332,000
NR1LW1ISL1SAVSCL2RH1	1.00	1,450,000	1,455,00	16,000	0.0019	8,384,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	60,000	0.0038	15,969,000

Table B-15. RESULTS OF 100 PERCENT IMPORTANCE ON SECONDARY PRODUCTION INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL3RH0	0.48	147,000	304,000	147,000	0.4830	304,000
NR0LW0ISL0SAVSCL2RH0	0.55	171,000	311,000	24,000	0.0670	361,000
NR0LW0ISL0SAVSCL2RH5	0.70	407,000	585,000	236,000	0.1457	1,620,000
NR0LW0ISL0SAVSCL2RH2	0.82	750,000	914,000	343,000	0.1249	2,743,000
NR0LW0ISL0SAVSCL2RH1	0.97	1,204,000	1,235,000	454,000	0.1543	2,941,000
NR0LW0ISL3SAVSCL2RH1	0.99	1,304,000	1,321,000	100,000	0.0125	8,053,000
NR0LW0ISL1SAVSCL2RH1	1.00	1,413,000	1,417,000	109,000	0.0096	11,292,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,473,000	60,000	0.0028	21,766,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,494,000	21,000	0.0001	157,366,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	16,000	0.0001	158,332,000

Table B-16. RESULTS OF 100 PERCENT IMPORTANCE ON BIBI INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.76	171,000	226,000	171,000	0.7588	226,000
NR0LW0ISL0SAVSCL2RH5	0.82	407,000	494,000	236,000	0.0657	3,595,000
NR0LW0ISL0SAVSCL2RH2	0.89	750,000	838,000	343,000	0.0699	4,899,000
NR0LW0ISL0SAVSCL2RH1	0.96	1,204,000	1,249,000	454,000	0.0696	6,525,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,413,000	1,423,000	209,000	0.0287	7,285,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,473,000	1,475,000	60,000	0.0059	10,094,000
NR0LW1ISL1SAVSCL1RH1	1.00	1,494,000	1,495,000	21,000	0.0008	25,890,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,510,000	1,510,000	16,000	0.0006	26,123,000

Wetland Restoration/Diversification Sites

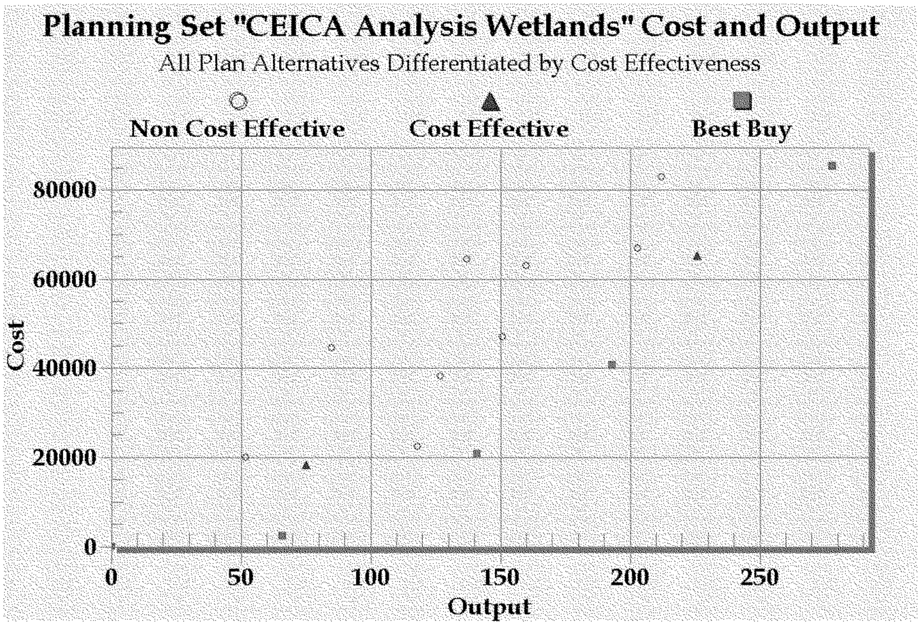
As discussed previously, the wetland restoration sites were valued using a different parameter than the rest of the restoration measures. Therefore, a separate CE/ICA was conducted on just these sites. The CE/ICA for the wetland restoration sites was relatively straight-forward, since only one output parameter was used to quantify the environmental benefits. Construction of each of the four sites are not considered mutually exclusive, so all possible combinations of the four sites were analyzed, resulting in a total of fifteen plans, in addition to the no action plan. The results of the cost-effective analysis indicate six plans, in addition to the no action plan, to be cost effective. The cost-effective plans can be found in the following table. Each of these plans is the least-costly means of providing the associated level of output or benefit for the wetland restoration sites.

Table B-17. RESULTS OF WETLANDS WITH RESTORATION COST EFFECTIVENESS ANALYSIS

Name	Wetland Function	Cost ($)	Average Cost ($)
No Action Plan	0.00	0.00	
PA0SG0MD1NG0	66.00	2,4.00	36
PA0SG1MD0NG0	75.00	18,300	244
PA0SG1MD1NG0	141.00	20,800	148
PA0SG1MD1NG1	193.00	40,700	211
PA1SG1MD1NG0	226.00	65,300	289
PA1SG1MD1NG1	278.00	85,300	307

Figure 3 illustrates the cost-effective analysis results, showing average annual environmental benefits (horizontal axis) and average annual costs (vertical axis) of the eight alternatives, as well as the No Action Plan, which is carried forward for comparison purposes only.

Figure B-3. WETLANDS RESTORATION COST-EFFECTIVE PLANS

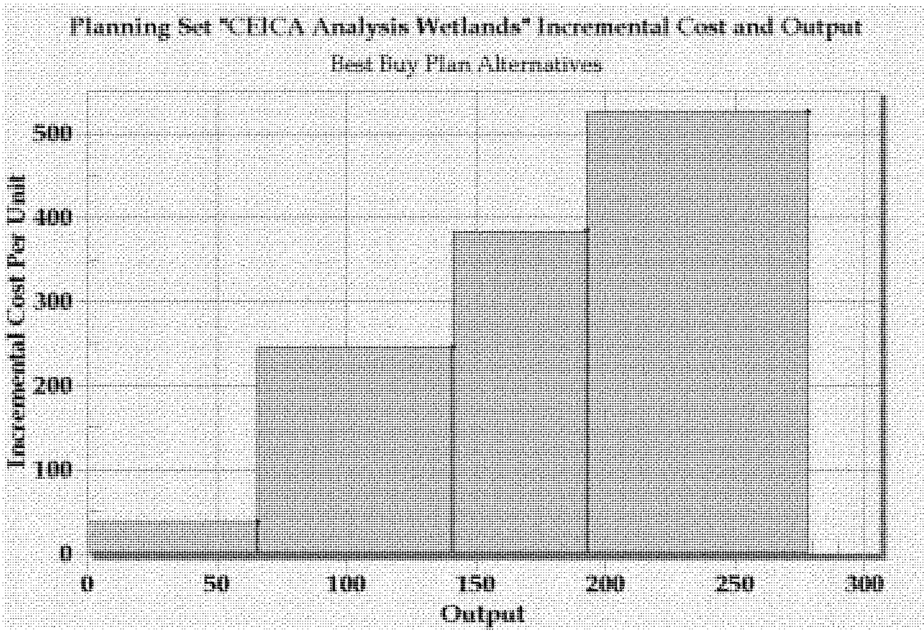


After conducting the cost effectiveness analysis, incremental cost analysis examines the changes in costs and changes in environmental benefits for each additional increment of output. The results of the incremental cost analysis on the wetland restoration sites indicated four of the considered plans, in addition to the no action plan, to be best buy plans. The following table summarizes the information from the incremental cost analysis of the alternatives, and Figure 4 displays the information graphically.

Table B-18. RESULTS OF WETLANDS RESTORATION INCREMENTAL COST ANALYSIS (BEST BUY PLANS)

Plan Alternative	Wetland Score	Cost ($)	Average Cost ($)	Incremental Cost ($)	Incremental Output	Incremental Cost per Output
No Action Plan	0.00	0.00				
PA0SG0MD1NG0	66.00	2,400	36	2400	66.0000	36
PA0SG1MD1NG0	141.00	20,800	148	18,300	75.0000	244
PA0SG1MD1NG1	193.00	40,700	211	19,900	52.0000	383
PA1SG1MD1NG1	278.00	85,300	307	44,600	85.0000	525

Figure 4. WETLANDS WITH PHRAGMITES ERADICATION BEST BUY PLANS



SELECTION OF AN ECOSYSTEM RESTORATION PLAN

When selecting a single alternative plan for recommendation from all those that have been considered, the criteria used to select the NER Plan include all the evaluation criteria discussed previously. Selecting the NER Plan requires careful consideration of the plan that meets planning objectives and constraints and reasonably maximizes environmental benefits while passing tests of cost effectiveness and incremental cost analysis, significance of outputs, acceptability, completeness, efficiency, and effectiveness.

The results of the cost effective and incremental cost analysis using the MCDA score derived using only secondary production and species diversity (0% weight on TSS reduction, 50% weighting on secondary production, and 50% weighting on species diversity) is used in selection of an NER plan. For plans including measures related to SAV, reef habitat, scallops, and wetland construction, the results of the cost effectiveness and incremental cost analyses indicate there are eight Best Buy Plans in addition to the No Action Plan. The results of this analysis were compared in conjunction with the results of the original analysis and the other sensitivity analyses. The cross-section of best buy plans from the different cost effectiveness and incremental cost analyses totaled 13 best buys plans, which include the following.

Table B-19. BEST BUY PLANS IDENTIFIED BY CE/ICA

Best Buy Plan	Description
RH5	Reef habitat in Broad Bay on normal foundation sites.
SAVSCL3	Suitable SAV in Main Stem and Broad Bay
*SAVSCL2	Suitable SAV in Main Stem and Broad Bay and Key Scallops in Main Stem and Broad Bay.
*SAVSCL2RH5	Suitable SAV in Main Stem and Broad Bay and Key Scallops in Main Stem and Broad Bay, and reef habitat in Broad Bay on normal foundation sites.
*SAVSCL2RH2	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on normal foundation sites.

*SAVSCL2RH1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites.
SAVSCL2RH1ISL3	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, and Fish House Island (Small Design).
*SAVSCL2RH1ISL1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, and Fish House Island (Large Design).
*SAVSCL1RH1ISL1	Suitable SAV and Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, and Fish House Island (Large Design).
SAVSCL2RH1ISL1LW1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, Fish House Island (Large Design), and Lake Windsor wetland.
*SAVSCL1RH1ISL1LW1	Suitable SAV and Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, Fish

	House Island (Large Design), and Lake Windsor wetland.
SAVSCL2RH1ISL1LW1NR1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, Fish House Island (Large Design), Lake Windsor and Narrows to Rainy Gut wetlands.
*SAVSCL1RH1ISL1LW1NR1	Suitable SAV and Scallops in Main Stem and Broad Bay, reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, Fish House Island (Large Design), Lake Windsor and Narrows to Rainy Gut wetlands.

*Best buy plans identified by the CE/ICA on MCDA scores with equal weighting of parameters and the CE/ICA on MCDA scores derived using only secondary production and species diversity (0% weight on TSS reduction).

Of these 13 plans, five plans were ruled out because each was identified by a best buy plan by only one of the sensitivity analyses and not by the CE/ICA using the MCDA score derived using only secondary production and species diversity (0% weight on TSS reduction, 50% weighting on secondary production, and 50% weighting on species diversity). These five plans are identified by a single asterisk in the previous table. Another three plans were ruled out based on significantly higher incremental cost per output as compared to other best buy plans. These three plans are identified by a double asterisk in the previous table. After this, five best buy plans were left to be carried forward for consideration. The plans carried forward for consideration include the following. Each of the plans carried forward for consideration was identified as a best buy plan by the main CE/ICA analysis with equal weights on the importance of each parameter as well as the CE/ICA using the MCDA score derived using only secondary production and species diversity (0% weight on TSS reduction, 50% weighting on secondary production, and 50% weighting on species diversity). .

Table B-20. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

Alternative plan	Code	Description
A	SAVSCL2	Suitable SAV in Main Stem and Broad Bay and Key Scallops in Main Stem and Broad Bay.
B	SAVSCL2RH5	Suitable SAV in Main Stem and Broad Bay and Key Scallops in Main Stem and Broad Bay, and reef habitat in Broad Bay on normal foundation sites.
C	SAVSCL2RH2	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on normal foundation sites.
D	SAVSCL2RH1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay, and reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites.
E	SAVSCL2RH1ISL1	Suitable SAV in Main Stem and Broad Bay, Key Scallops in Main Stem and Broad Bay,

reef habitat in Lynnhaven Bay and Broad Bay on both normal and soft foundation sites, and Fish House Island (Large Design).

Of the Best Buy Plans, Alternative D best meets the planning objectives while reasonably maximizing the environmental benefits. This plan includes the Suitable SAV in both Broad Bay and the main stem, Key scallops in both Broad Bay and the main stem, and both low relief reef habitat and high relief reef habitat (on normal and soft foundations). In addition to being identified as a best buy plan by the CE/ICA on the MCDA score derived using only secondary production and species diversity (0% weight on TSS reduction, 50% weighting on secondary production, and 50% weighting on species diversity), this plan was also identified as a Best Buy Plan by all of the other CE/ICAs conducted for the sensitivity analysis on the weights applied to each benefit parameter.

The increase in average annual output outweighs the additional average annual cost for Alternatives A, B, C and D for all of the analyses, whereas this is not the case for Alternative E. For the MCDA analysis with 50% weighting on secondary production, and 50% weighting on species diversity, the incremental cost per output for Alternative E is $4,4,178,000 more than for Alternative D, which, in turn, would only increase secondary production by about 6,500 kg more on average annually. In addition to the considerably higher incremental cost per unit of output, the plan with the island has several significant risks involved with construction of the island.

The intent of the Fish House Island Plan is to restore pre-existing vegetated wetland habitat. Several conditions related to the adjacent Federal navigation channel and inlet orientation would present significant challenges to the constructability and maintenance of the proposed island. Swift currents in the vicinity would require substantial shoreline armoring to confine fill material within the historic footprint. The orientation of the inlet opening to the north allows a higher percentage of larger, northeast waves to impact the proposed island. Given the magnitude of all of these risks, Alternative E was, therefore, removed from consideration.

Alternative A includes only measures of SAV and scallops. While this alternative is efficient and effective, it is not complete in terms of fully meeting the objectives of the project. Because of this, the plan is not as acceptable as the other alternatives carried forward for consideration. Alternative A was, therefore, removed from consideration.

The average annual incremental cost per unit of output for Alternative D is approximately $540,000 more than the next lower output best buy plan, Alternative C. However, this plan includes both the normal and soft foundation sites for the reef habitat, rather than just the normal foundation sites. Inclusion of these soft foundation sites increases secondary production by 45,000 kg more on average annually. While the average cost per acre to construct the reef habitat sites with soft foundations is significantly higher as compared to the reef habitat sites with normal foundations, it is still worth it to produce this additional level of output when considered along with all the other components of the restoration project.

Wetland Restoration/ Diversification Sites

The results of the cost effectiveness and incremental cost analyses on the wetland restoration sites indicate there are seven cost-effective plans, of which there are four Best Buy Plans, in addition to the No Action Plan.

Table B-21. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

Alternative plan	Code	Description
1	PA0SG0MD1NG0	Mill Dam Creek site.
2	PA0SG1MD1NG0	South Great Neck and Mill Dam Creek sites.
3	PA0SG1MD1NG1	South Great Neck, Mill Dam Creek, and North Great Neck sites.
4	PA1SG1MD1NG1	Princess Anne High School, South Great Neck, Mill Dam Creek, and North Great Neck sites.

The results of this analysis were analyzed to determine the plan with the best value of the plans evaluated. Of the Best Buy Plans, Alternative 4, with construction of all four wetlands with *P. australis* eradication sites, best meet the planning objectives while reasonably maximizing the environmental benefits. There is a significant difference in incremental cost per output between the alternative with construction of just Mill Dam Creek and the other alternatives. However, the Mill Dam Creek site is limited to less than one acre. When comparing the cost per acre of the most expensive site, the Princess Anne site, to the construction cost of the average wetland in the study area, the cost per acre of the Princess Anne site, just over $200,000, is seen as a considerable value. The Mill Dam Creek, North Great Neck, and South Great Neck sites would be considered an exceptional value, all under $40,000 per acre, in this comparison.

RISK AND UNCERTAINTY

Sensitivity Analysis on Uncertainty of Project Costs and Risk of Project Success

Risk and uncertainty were considered throughout the entire process of plan formulation and evaluation of the alternative plans. However, a sensitivity analysis was conducted on the results of the CE/ICA to account for any risk and uncertainty that could not be accounted for through the design of the projects or the estimation of the project benefits. The purpose of this sensitivity analysis is to validate the recommendation of the NER Plan with consideration of the uncertainty of project costs and the risk of project success.

The risk associated with success of the SAV component of the project is the highest. Scallops were considered to have a relatively high risk as well, due to their dependency on SAV as well as their own establishment. Therefore, CE/ICA was conducted with the costs for the SAV/scallop measures increased by 50 percent and again with costs increased by 100 percent. There was no effect on the outcome of the best buy plans identified to be carried forward for consideration with a 50 percent or 100 percent cost increase on the SAV/scallop measures. The results of the incremental cost analysis with SAV/scallop costs increased by 50 percent can be seen in the following table.

It is recognized that there is a risk associated with construction of the reef habitat. Therefore, CE/ICA was run with the costs for this measure increased by 50 percent to account for this risk. With a 50 percent increase in reef habitat costs, there was no change to the plans identified as best buy plans by the analysis.

A sensitivity analysis was also conducted on the separate wetland analysis. There is inherent risk associated with the success of growing native species in place of invasive species. To account for this, CE/ICA was rerun with a 25 percent cost increase applied to the Great Neck North and Princess Anne High School sites. This resulted in different incremental costs per output, but no change in the best buy plans identified by the analysis.

The results of the sensitivity analyses on uncertainty of costs and risk of project success can be seen in the following tables.

Table B-22. RESULTS OF 50 PERCENT COST INCREASE ON SAV/SCALLOPS INCREMENTAL COST ANALYSI

Plan Alternative	Score (Output)	Cost	Average Cost	Incremental Cost	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.48	257,000	530,000	257,000	0.4845	530,000
NR0LW0ISL0SAVSCL2RH5	0.64	493,000	769,000	236,000	0.1561	1,512,000
NR0LW0ISL0SAVSCL2RH2	0.78	835,000	1,072,000	343,000	0.1387	2,470,000
NR0LW0ISL0SAVSCL2RH1	0.94	1,289,000	1,365,000	454,000	0.1654	2,745,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,499,000	1,508,000	209,000	0.0493	4,245,000
NR0LW1ISL1SAVSCL2RH1	0.99	1,520,000	1,527,000	201,000	0.0012	18,182,000
NR1LW1ISL1SAVSCL2RH1	1.00	1,535,000	1,542,000	16,000	0.0009	18,308,000
NR1LW1ISL1SAVSCL1RH1	1.00	1,625,000	1,625,000	90,000	0.0042	21,673,000

Table B-23. RESULTS OF 100 PERCENT COST INCREASE ON SAV/SCALLOPS INCREMENTAL COST ANALYSIS

Plan Alternative	Score (Output)	Cost	Average Cost	Incremental Cost	Inc. Output	Inc. Cost Per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.48	342,000	707,000	342,000	0.4845	707,000
NR0LW0ISL0SAVSCL2RH5	0.64	578,0.00	903,000	236,000	0.1561	1,512,000
NR0LW0ISL0SAVSCL2RH2	0.78	921,000	1,182,000	343,000	0.1387	2,471,000
NR0LW0ISL0SAVSCL2RH1	0.94	1,375,0.00	1,456,000	454,000	0.1654	2,745,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,584,000	1,594,000	209,000	0.0493	4,245,000
NR0LW1ISL1SAVSCL2RH1	0.99	1,605,000	1,613,000	21,0000	0.0012	18,182,000
NR1LW1ISL1SAVSCL2RH1	1.00	1,621,000	1,628,000	16,000	0.0009	18,308,000
NR1LW1ISL1SAVSCL1RFH1	1.00	1,741,000	1,741,000	120,000	0.0042	28,898,000

Table B-24. RESULTS OF 50 PERCENT COST INCREASE ON REEF HABITAT INCREMENTAL COST ANALYSIS

Plan Alternative	Score (Output)	Cost	Average Cost	Incremental Cost	Inc. Output	Inc. Cost per Output
No Action Plan	0.00	0.00				
NR0LW0ISL0SAVSCL2RH0	0.48	171,000	353,000	171,000	0.4845	353,000
NR0LW0ISL0SAVSCL2RH5	0.64	525,000	820,000	354,000	0.1561	2,268,000
NR0LW0ISL0SAVSCL2RH2	0.78	1,039,000	1,3334,000	514,000	0.1387	3,706,000
NR0LW0ISL0SAVSCL2RH1	0.94	1,720,000	1,821,000	681,000	0.1654	4,118,000
NR0LW0ISL1SAVSCL2RH1	0.99	1,929,000	1,941,000	209,000	0.0493	4,245,000
NR0LW0ISL1SAVSCL1RH1	1.00	1,989,000	1,993,000	60,000	0.0042	14,449,000
NR0LW1ISL1SAVSCL1RH1	1.00	2,010,000	2,012,000	21,000	0.0012	18,182,000
NR1LW1ISL1SAVSCL1RH1	1.00	2,026,000	2,026,000	16,000	0.0009	18,308,000

Table B-25. RESULTS OF WETLANDS SENSITIVITY INCREMENTAL COST ANALYSIS

Plan Alternative	Wetland Function (Output)	Cost	Average Cost	Incremental Cost	Inc. Output	Inc. Cost per Output
No Action Plan	0.00	0.00				
PA0SG0MD1NG0	66.00	2,400	36.8788	2,400	66.0000	36
PA0SG1MD1NG0	141.00	20,800	147.1702	18,300	75.0000	244
PA0SG1MD1NG1	193.00	45,600	236.4948	24,900	52.0000	479
PA1SG1MD1NG1	278.00	101,400	364.6844	55,700	85.0000	656

APPENDIX C

ENVIRONMENTAL

APPENDIX C

ENVIRONMENTAL

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APPENDIX C

ENVIRONMENTAL

PURPOSE

The purpose of this appendix is to provide detailed environmental information concerning aspects of the study area. More specifically, it includes tables referenced in the main body of the report, the Section 404(b)(1) evaluation, the NMFS essential fish habitat designations analysis, the adaptive management plan, the coastal zone management summary and the USFWS coordination act report.

TABLES

This section includes tables which have been referenced in the main body of the report. The tables describe the fauna that resides within the Lynnhaven River Basin.

Table C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic Group	Scientific Name	1979	1983	1982a	1982b	2007
Cnidaria : Anthozoa	*Anthozoa spp.*					X
	Edwardsia elegans					X
	Haliplanella luciae				X	
Platyhelminthes : Turbellaria	*Stylochus ellipticus*					X
	Turbellaria spp.					X
Nemertea	*Nemertea spp.*		X			X
Annelida: Polychaeta	*Ancistrosyllis hartmanae*					X
	Ancistrosyllis jonesi					X
	Ancistrosyllis spp.					
	Ampharete americana					
	Apoprionospio pygmaea					X
	Arabella iricolor					X
	Asabellides oculata					
	Bhawania heteroseta					X
	Brania clavata					X
	Cabira incerta					X
	Capitella spp.		X			
	Capitella capitata	X	X			X
	Capitellid spp.		X			

Table C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic Group	Scientific Name	1979	1983	1982a	1982b	2007
Annelida: Polychaeta	*Capitella capitata*	X	X			X
	Capitellid spp.		X			
	Carazziella hobsonae					X
	Caulleriella killariensis					X
	Caulleriella sp.		X			
	Chautozone sp.					
	Cirrophorus furcatus					X
	Cirratulidae sp.					
	Cistena gouldii		X			
	Clymenella torquata		X	X	X	X
	Demonax microphthalmus					X
	Diopatra cuprea					X
	Dorvillea rudolphi					X
	Drilonereis longa					X
	Eteone heteropoda		X	X	X	X
	Eteone lactea					X
	Exogone dispar					X
	Glycera americana					X
	Glucera capitata		X			

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic Group	Scientific Name	1979	1983	1982a	1982b	2007
Annelida: Polychaeta	*Glycera dibranchiata*		X			X
	Glycera spp.					X
	Glycinde solitaria		X	X		X
	Gyptis brevipalpa		X			
	Gyptis crypta					X
	Gyptis vittata			X	X	
	Harmothoe extenuata				X	
	Hauchiella sp.					X
	Heteromastus filiformis	X	X	X	X	X
	Hobsonia florida					X
	Hydroides dianthus		X		X	X
	Laeonereis culveri	X				X
	Leitoscoloplos spp.					
	Lepidonotus sublevis					X
	Loimia medusa					X
	Lysippides greyi					
	Macroclymene zonalis					X
	Magelona sp.					X
	Maldanidae spp.					X

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Annelida: Polychaeta	*Malmgreniella taylori*					X
	Marenzelleria viridis					X
	Mediomastus ambiseta		X	X	X	X
	Microphthalmus aberrans					
	Microphthalmus similis		X			
	Nereis succinea	X	X	X	X	X
	Nephtys bucera					X
	Nephtys picta					X
	Notomastus sp. A Ewing					X
	Ophelia bicornia		X			
	Paraonis fulgens		X			X
	Parapionosyllis longicirrata		X			X
	Paraprionospio pinnata		X			X
	Pectinaria gouldii					X
	Peloscolex gabriellae	X				
	Phyllodoce arenae		X			X
	Podarke obcura		X		X	
	Podarkeopsis levifuscina					X
	Polydora cornuta					X
	Polydora lingi		X	X	X	

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Annelida: Polychaeta	*Polydora websteri*				X	
	Potamilla sp.		X			
	Prionospio perkinsi					X
	Pseudoeurythoe ambigua					
	Sabaco elongatus					X
	Sabella microphthalma				X	
	Sabellaria vulgaris		X		X	X
	Schistomeringos rudolphi		X		X	
	Scolecolepides viridis		X			
	Scolelepis texana					X
	Scoloplos fragilis			X		X
	Scoletoma tenuis					X
	Sigambra tentaculata					X
	Sphaerosyllis hystrix		X			
	Spiochaetopterus costarum					X
	Spiochaetopterus oculatus			X		
	Spiophanes bombyx		X			X
	Streblospio benedicti	X	X	X	X	X
	Streptosyllis sp.		X			
	Strio pettiboneae					X

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Annelida: Polychaeta	*Streptosyllis sp.*		X			
	Strio pettiboneae					X
	Syllides fulva					X
	Syllides verrilli				X	
	Travisia spp.			X	X	
	Travisia spp.					X
Annelida : Oligochaeta	*Oligochaeta spp.*					X
	Peloscolex gabriellae					
	Tubificoides heterochaetus					X
	Tubificoides sp.		X			
	Tubificoides spp. Group I					X
	Tubificoides wasselli					X
Mollusca: Gastropod	*Acteocina canaliculata*					X
	Crepidula fornicata				X	X
	Doridella obscura					X
	Gastropoda spp.					X
	Haminoea solitaria					X
	Ilyanassa obsoleta		X		X	X
	Mitrella lunata				X	

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Tourettellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Mollusca: Gastropod	*Nassarius vibex*					X
	Nudibranchia spp.					X
	Odostomia spp.					X
	Polinices duplicata					X
	Rictaxis punctostriatus					X
	Sphaerosyllis taylori					X
Mollusca : Bivalvia	*Aligena elevata*					X
	Bivalvia spp.					X
	Cyrtopleura costata					X
	Gemma gemma		X			X
	Macoma balthica	X				X
	Macoma mitchelli					X
	Macoma tenta					X
	Mercenaria mercenaria					X
	Mulinia lateralis			X		X
	Mya arenaria	X				
	Mysella planulata					X
	Tagelus divisus					X
	Tagelus plebeius	X				X
	Tellina agilis		X	X		X

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Mollusca : Bivalvia	*Tellinidae spp.*					X
Arthropoda: Isopoda	*Chiridotea nigrescens*		X			X
	Cyathura polita					X
	Edotea triloba				X	X
	Erichsonella sp.				X	
	Ptilanthura tenuis					X
Arthropoda: Amphipoda	*Acanthohaustorius intermedius*		X			X
	Acanthohaustorius millsi		X			X
	Ameroculodes species complex					X
	Ampelisca abdita					
	Ampelisca spp.					X
	Ampelisca verrilli					X
	Ampithoe valida					X
	Caprella penantis		X			
	Caprella sp.				X	
	Cerapus tubularis					X
	Corophium lacustre					X
	Corophium sp.					
	Corophium tuberculatum		X		X	
	Cymadusa compta				X	

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
Arthropoda: Amphipoda	*Elasmopus levis*				X	
	Erichthonius brasiliensis		X		X	X
	Gammarus mucronatus				X	
	Leptocheirus plumulosus				X	
	Listriella barnardi					X
	Listriella clymenellae		X			X
	Monocorophium tuberculatum					X
	Paracaprella tenuis		X			X
	Parametopella cypris		X			
	Protohaustorius deichmannae		X			
	Unicola serrata		X			
Arthropoda : Cumacea	*Cyclaspis varians*		X			X
	Leucon americanus					X
Arthropoda: Decapoda	*Alpheus heterochaelis*					X
	Callinectes sapidus			X	X	X
	Hippolyte pleuracanthus					X
	Ogyrides alphaerostris					X
	Palaemonetes pugio			X		
	Pagurus acadianus					X
	Pagurus longicarpus					X

C-1. INVERTEBRATES COLLECTED FROM SITES LOCATED IN THE LYNNHAVEN SYSTEM (Cont'd)

		Study				
		Dauer *et al*	Touretellotte & Dauer	Dauer *et al*	Dauer *et al*	Dauer
Taxonomic group	Scientific name	1979	1983	1982a	1982b	2007
	Pinnixa spp.					X
Arthropoda : Mysidacea	*Mysidopsis bigelowi*					X
Arthropoda: Tanaidacea	*Leptognatha caeca*					X
Phoronida	*Phoronis psammophila*			X		
	Phoronis spp.					X
Echinodermata : Holothuroidea	*Leptosynapta tenuis*					X
Echinodermata : Ophiuroidea	*Microphiopholis atra*					X
Chordata: Hemichordata	*Hemichordata spp.*					X
	Saccoglossus kowalevskii					X
Chordata : Cephalochordata	*Branchiostoma virginae*		X			X
Chordata : Urochordata	*Molgula lutlulenta*					X
	Molgula manhattensis		X		X	

Source: Dauer, D.M., W.W. Robinson, C.P. Seymour, and A.T. Leggett, Jr. 1979. Effects of nonpoint pollution on benthic invertebrates in the Lynnhaven River system. Bulletin of Virginia Water Resource Center 117:112, Tourtellotte, G.H. and D.M. Dauer. 1983. Macrobenthic communities of the lower Chesapeake Bay. II. Lynnhaven Roads, Lynnhaven River, Broad Bay, and Linkhorn Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 68:59-72, Dauer, D.M., R.M. Ewing, G.H. Tourtellotte, W.T. Harlan, J.W. Sourbeer and H. R. Barker Jr. 1982a. Predation, resource limitation and the structure of benthic infaunal communities of the lower Chesapeake Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 67(4):477-489, Dauer, D.M., G.H. Tourtellotte, and R.M. ewing. 1982b. Oyster shells and artificial worm tubes: The role of refuges in structuring benthic communities of the lower Chesapeake Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 67(5):661-677, Dauer, D.M., 2007. Benthic biological monitoring of the Lynnhaven River. Old Dominion University, Norfolk VA.

Table C-2. MACROINVERTEBRATES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Mussel, eastern elliptio	*Elliptio complanata*
Crayfish	*Fallicambarus uhleri*
Crayfish	*Fallicambarus fodiens*
Crayfish, devil	*Cambarus diogenes diogenes*
Crayfish, no common name	*Cambarus acuminatus*
Crayfish, White River	*Procambarus acutus*

Source: VDGIF Online Database (latitude 36°51′59.7″ and longitude 76°03′ 54.9″), 2010.

Table C-3. FISH OCCURING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Bass, largemouth	*Micropterus salmoides*
Bass, smallmouth	*Micropterus dolomieu*
Bass, striped	*Morone saxatilis*
Bass, white	*Morone chrysops*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia calva*
Bullhead, brown	*Ameiurus nebulosus*
Bullhead, yellow	*Ameiurus natalis*
Carp, common	*Cyprinus carpio*
Catfish, channel	*Ictalurus punctatus*
Catfish, white	*Ameiurus catus*
Crappie, black	*Pomoxis nigromaculatus*
Dace, rosyside	*Clinostomus funduloides*
Darter, swamp	*Etheostoma fusiforme*
Gar, longnose	*Lepisosteus osseus*
Killifish, banded	*Fundulus diaphanus*
Killifish, marsh	*Fundulus confluentus*
Lamprey, sea	*Petromyzon marinus*
Minnow, eastern silvery	*Hybognathus regius*
Mosquitofish, eastern	*Gambusia holbrooki*
Mudminnow, eastern	*Umbra pygmaea*
Perch, white	*Morone americana*
Perch, yellow	*Perca flavescens*
Pickerel, chain	*Esox niger*
Pickerel, redfin	*Esox americanus americanus*
Pumpkinseed	*Lepomis gibbosus*
Shad, gizzard	*Dorosoma cepedianum*
Shad, threadfin	*Dorosoma petenense*
Shiner, golden	*Notemigonus crysoleucas*
Sunfish, bluespotted	*Enneacanthus gloriosus*
Sunfish, redear	*Lepomis microlophus*
Walleye	*Sander vitreus vitreus*
Warmouth	*Lepomis gulosus*

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010.

Table C-4. FISH ASSEMBLAGES FOUND IN TIDAL CREEKS SURVEYED IN THE LYNNHAVEN RIVER.

COMMON NAME	SCIENTIFIC NAME
Atlantic Silverside	*Menidia menidia*
Bay anchovy	*Anchoa mitchilli*
Silver perch	*Bairdiella chrysoura*
Gizzard shad	*Dorosoma cepedianum*
Atlantic menhaden	*Brevoortia tyrannus*
Mummichog	*Fundulus heteroclitus*
Blue Crab	*Callinectes sapidus*
Spot	*Leiostomus xanthurus*
Striped mullet	*Mugil cephalus*
Striped anchovy	*Anchoa hepsetus*
Atlantic croaker	*Micropogonias undulatus*
Red drum	*Sciaenops ocellatus*
White perch	*Marone americana*
Striped killifish	*Fundulus majalis*
Spotfin mojarra	*Eucinostomus argenteus*
American eel	*Anguilla rostrata*
Striped bass	*Morone saxatilis*
Summer flounder	*Paralichthys dentatus*
Naked goby	*Gobiosoma bosc*
Blackcheek tonguefish	*Symphurus plagiusa*
Bluefish	*Pomatomus saltatrix*
Permit	*Trachinottus falcatus*
Sheepshead minnow	*Cyprinodon variegatus*
Crevalle jack	*Caranx hippos*
Hogchoker	*Trinectes maculatus*
Ladyfish	*Elops saurus*
Sharptail goby	*Gobionellus oceanicus*
Spotted seatrout	*Cynoscion nebulosus*
Tripletail	*Lobotes surinamensis*
Weakfish	*Cynoscion regalis*

Source: Bilkovic D. M., D. Stanhope and K. Angstadt. 2007. Shallow water fish communities and coastal development stressors in the Lynnhaven River. Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Table C-5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Anhinga	*Anhinga anhinga*
Avocet, American	*Recurvirostra americana*
Blackbird, Brewer's	*Euphagus cyanocephalus*
Blackbird, red-winged	*Agelaius phoeniceus*
Blackbird, yellow-headed	*Xanthocephalus xanthocephalus*
Bluebird, eastern	*Sialia sialis*
Bobolink	*Dolichonyx oryzivorus*
Bufflehead	*Bucephala albeola*
Bunting, indigo	*Passerina cyanea*
Bunting, lark	*Calamospiza melanocorys*
Bunting, Lazuli	*Passerina amoena*
Bunting, painted	*Passerina ciris ciris*
Bunting, snow	*Plectrophenax nivalis nivalis*
Canvasback	*Aythya valisineria*
Cardinal, northern	*Cardinalis cardinalis*
Chickadee, Carolina	*Poecile carolinensis*
Coot, American	*Fulica americana*
Cormorant, double-crested	*Phalacrocorax auritus*
Cormorant, great	*Phalacrocorax carbo*
Cowbird, brown-headed	*Molothrus ater*
Crossbill, white-winged	*Loxia leucoptera*
Crow, American	*Corvus brachyrhynchos*
Crow, fish	*Corvus ossifragus*
Cuckoo, black-billed	*Coccyzus erythropthalmus*
Curlew, long-billed	*Numenius americanus*
Dove, common ground	*Columbina passerina*
Dove, mourning	*Zenaida macroura carolinensis*
Dovekie	*Alle alle*
Dowitcher, long-billed	*Limnodromus scolopaceus*
Duck, Harlequin	*Histrionicus histrionicus*
Duck, long-tailed	*Clangula hyemalis*
Duck, ring-necked	*Aythya collaris*
Duck, ruddy	*Oxyura jamaicensis*
Duck, wood	*Aix sponsa*
Eagle, golden	*Aquila chrysaetos*
Egret, cattle	*Bubulcus ibis*
Egret, reddish	*Egretta rufescens rufescens*
Egret, snowy	*Egretta thula*
Eider, common	*Somateria mollissima*
Eider, king	*Somateria spectabilis*
Finch, house	*Carpodacus mexicanus*

Table C.5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Flamingo, greater	*Phoenicopterus ruber*
Flicker, northern	*Colaptes auratus*
Flycatcher, ash-throated	*Myiarchus cinerascens*
Flycatcher, great crested	*Myiarchus crinitus*
Flycatcher, scissor-tailed	*Tyrannus forficatus*
Frigatebird, magnificent	*Fregata magnificens*
Fulmar, northern	*Fulmarus glacialis*
Gadwall	*Anas strepera*
Gallinule, purple	*Porphyrula martinica*
Gannet, northern	*Morus bassanus*
Gnatcatcher, blue-gray	*Polioptila caerulea*
Goldeneye, common	*Bucephala clangula americana*
Goldfinch, American	*Carduelis tristis*
Goose, Canada	*Branta canadensis*
Goose, greater white-fronted	*Anser albifrons flavirostris*
Goose, lesser snow	*Chen caerulescens caerulescens*
Goose, Ross'	*Chen rossii*
Goose, snow	*Chen caerulescens*
Grackle, boat-tailed	*Quiscalus major*
Grackle, common	*Quiscalus quiscula*
Grebe, eared	*Podiceps nigricollis*
Grebe, pied-billed	*Podilymbus podiceps*
Grebe, red-necked	*Podiceps grisegena*
Grebe, western	*Aechmophorus occidentalis*
Grosbeak, black-headed	*Pheucticus melanocephalus*
Grosbeak, blue	*Guiraca caerulea caerulea*
Grosbeak, evening	*Coccothraustes vespertinus*
Gull, black-headed	*Larus ridibundus*
Gull, Bonaparte's	*Larus philadelphia*
Gull, Franklin's	*Larus pipixcan*
Gull, glaucous	*Larus hyperboreus*
Gull, great black-backed	*Larus marinus*
Gull, herring	*Larus argentatus*
Gull, Iceland	*Larus glaucoides*
Gull, laughing	*Larus atricilla*
Gull, lesser black-backed	*Larus fuscus*
Gull, little	*Larus minutus*
Gull, ring-billed	*Larus delawarensis*
Gull, Sabine's	*Xema sabini*
Hawk, Cooper's	*Accipiter cooperii*

Table C-5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Hawk, red-shouldered	*Buteo lineatus lineatus*
Hawk, red-tailed	*Buteo jamaicensis*
Hawk, rough-legged	*Buteo lagopus johannis*
Hawk, sharp-shinned	*Accipiter striatus velox*
Heron, great blue	*Ardea herodias herodias*
Hummingbird, ruby-throated	*Archilochus colubris*
Ibis, white	*Eudocimus albus*
Jaeger, parasitic	*Stercorarius parasiticus*
Jaeger, pomarine	*Stercorarius pomarinus*
Jay, blue	*Cyanocitta cristata*
Junco, dark-eyed	*Junco hyemalis*
Kestrel, American	*Falco sparverius sparverius*
Killdeer	*Charadrius vociferus*
Kingbird, gray	*Tyrannus dominicensis*
Kingbird, western	*Tyrannus verticalis*
Kingfisher, belted	*Ceryle alcyon*
Kinglet, ruby-crowned	*Regulus calendula*
Kite, Mississippi	*Ictinia mississippiensis*
Kite, swallow-tailed	*Elanoides forficatus forficatus*
Kittiwake, black-legged	*Rissa tridactyla*
Lark, horned	*Eremophila alpestris*
Longspur, Lapland	*Calcarius lapponicus*
Loon, common	*Gavia immer*
Loon, red-throated	*Gavia stellata*
Mallard	*Anas platyrhynchos*
Martin, purple	*Progne subis*
Merganser, common	*Mergus merganser americanus*
Merganser, hooded	*Lophodytes cucullatus*
Merganser, red-breasted	*Mergus serrator serrator*
Merlin	*Falco columbarius*
Mockingbird, northern	*Mimus polyglottos*
Murre, thick-billed	*Uria lomvia*
Nighthawk, common	*Chordeiles minor*
Nuthatch, white-breasted	*Sitta carolinensis*
Oriole, Baltimore	*Icterus galbula*
Oriole, orchard	*Icterus spurius*
Osprey	*Pandion haliaetus carolinensis*
Owl, barred	*Strix varia*
Owl, great horned	*Bubo virginianus*
Owl, short-eared	*Asio flammeus*
Pelican, American white	*Pelecanus erythrorhynchos*
Phalarope, red	*Phalaropus fulicarius*
Phalarope, red-necked	*Phalaropus lobatus*
Phalarope, Wilson's	*Phalaropus tricolor*
Pheasant, ring-necked	*Phasianus colchicus*

Table C-5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Phoebe, eastern	*Sayornis phoebe*
Phoebe, Say's	*Sayornis saya*
Pigeon, rock	*Columba livia*
Pintail, northern	*Anas acuta acuta*
Pintail, white-cheeked	*Anas bahamensis*
Pipit, American	*Anthus rubescens*
Plover, semipalmated	*Charadrius semipalmatus*
Puffin, Atlantic	*Fratercula artica*
Redpoll, common	*Carduelis flammea*
Redstart, American	*Setophaga ruticilla*
Robin, American	*Turdus migratorius*
Ruff	*Philomachus pugnax*
Sanderling	*Calidris alba*
Sandpiper, least	*Calidris minutilla*
Sandpiper, pectoral	*Calidris melanotos*
Sandpiper, semipalmated	*Calidris pusilla*
Sandpiper, spotted	*Actitis macularia*
Sandpiper, western	*Calidris mauri*
Scaup, lesser	*Aythya affinis*
Scoter, black	*Melanitta nigra americana*
Scoter, surf	*Melanitta perspicillata*
Scoter, white-winged	*Melanitta fusca deglandi*
Screech-owl, eastern	*Megascops asio*
Shearwater, Audubon's	*Puffinus lherminieri lherminieri*
Shearwater, Cory's	*Calonectris diomedea borealis*
Shearwater, greater	*Puffinus gravis*
Shearwater, sooty	*Puffinus griseus*
Shoveler, northern	*Anas clypeata*
Siskin, pine	*Carduelis pinus*
Snipe, common	*Gallinago gallinago*
Sora	*Porzana carolina*
Sparrow, American tree	*Spizella arborea*
Sparrow, black-throated	*Amphispiza bilineata*
Sparrow, chipping	*Spizella passerina*
Sparrow, clay-colored	*Spizella pallida*
Sparrow, fox	*Passerella iliaca*
Sparrow, house	*Passer domesticus*
Sparrow, lark	*Chondestes grammacus*
Sparrow, Le Conte's	*Ammodramus leconteii*
Sparrow, Lincoln's	*Melospiza lincolnii*
Sparrow, savannah	*Passerculus sandwichensis*
Sparrow, song	*Melospiza melodia*
Sparrow, swamp	*Melospiza georgiana*
Sparrow, vesper	*Pooecetes gramineus*
Sparrow, white-crowned	*Zonotrichia leucophrys*

Table C-5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Sparrow, white-throated	*Zonotrichia albicollis*
Starling, European	*Sturnus vulgaris*
Stilt, black-necked	*Himantopus mexicanus*
Stint, Temminck's	*Calidris temminckii*
Stork, wood	*Mycteria americana*
Swallow, barn	*Hirundo rustica*
Swallow, tree	*Tachycineta bicolor*
Swan, tundra	*Cygnus columbianus columbianus*
Tanager, summer	*Piranga rubra*
Tanager, western	*Piranga ludoviciana*
Teal, blue-winged	*Anas discors orphna*
Teal, green-winged	*Anas crecca carolinensis*
Tern, Arctic	*Sterna paradisaea*
Tern, bridled	*Sterna anaethetus*
Thrush, Swainson's	*Catharus ustulatus*
Titmouse, tufted	*Baeolophus bicolor*
Towhee, green-tailed	*Pipilo chlorurus*
Turkey, wild	*Meleagris gallopavo silvestris*
Turnstone, ruddy	*Arenaria interpres morinella*
Veery	*Catharus fuscescens*
Vireo, blue-headed	*Vireo solitarius*
Vireo, red-eyed	*Vireo olivaceus*
Vireo, white-eyed	*Vireo griseus*
Vulture, black	*Coragyps atratus*
Vulture, turkey	*Cathartes aura*
Warbler, bay-breasted	*Dendroica castanea*
Warbler, black-throated blue	*Dendroica caerulescens*
Warbler, blackburnian	*Dendroica fusca*
Warbler, blackpoll	*Dendroica striata*
Warbler, chestnut-sided	*Dendroica pensylvanica*
Warbler, hooded	*Wilsonia citrina*
Warbler, Nashville	*Vermivora ruficapilla*
Warbler, orange-crowned	*Vermivora celata*
Warbler, palm	*Dendroica palmarum*
Warbler, pine	*Dendroica pinus*
Warbler, Wilson's	*Wilsonia pusilla*
Warbler, yellow-rumped	*Dendroica coronata cornata*
Warbler, yellow-throated	*Dendroica dominica*
Waterthrush, northern	*Seiurus noveboracensis*
Waxwing, cedar	*Bombycilla cedrorum*
Whistling-duck, fulvous	*Dendrocygna bicolor*
Wigeon, American	*Anas americana*
Wigeon, Eurasian	*Anas penelope*
Willet	*Catoptrophorus semipalmatus semipalmatus*

Table C-5. AVIAN RESOURCES OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Woodpecker, downy	*Picoides pubescens medianus*
Woodpecker, hairy	*Picoides villosus*
Woodpecker, pileated	*Dryocopus pileatus*
Woodpecker, red-bellied	*Melanerpes carolinus*
Woodpecker, red-headed	*Melanerpes erythrocephalus*
Wren, Carolina	*Thryothorus ludovicianus*
Wren, house	*Troglodytes aedon*
Yellowlegs, greater	*Tringa melanoleuca*
Yellowlegs, lesser	*Tringa flavipes*
Yellowthroat, common	*Geothlypis trichas*

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010.

Table C-6. TERRESTRIAL MAMMALS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Bat, big brown	*Eptesicus fuscus fuscus*
Bat, eastern red	*Lasiurus borealis borealis*
Bat, evening	*Nycticeius humeralis humeralis*
Bat, hoary	*Lasiurus cinereus cinereus*
Bat, northern yellow	*Lasiurus intermedius floridanus*
Bat, seminole	*Lasiurus seminolus*
Bat, silver-haired	*Lasionycteris noctivagans*
Bear, black	*Ursus americanus americanus*
Beaver, American	*Castor canadensis*
Bobcat, Florida	*Lynx rufus floridanus*
Chipmunk, Fisher's eastern	*Tamias striatus fisheri*
Cottontail, eastern	*Sylvilagus floridanus mallurus*
Coyote	*Canis latrans*
Deer, white-tailed	*Odocoileus virginianus*
Fox, common gray	*Urocyon cinereoargenteus cinereoargenteus*
Fox, red	*Vulpes vulpes fulva*
Mink, common	*Mustela vison mink*
Mole, eastern	*Scalopus aquaticus aquaticus*
Mouse, common white-footed	*Peromyscus leucopus leucopus*
Mouse, eastern harvest	*Reithrodontomys humulis humulis*
Mouse, house	*Mus musculus musculus*
Mouse, Lewis' golden	*Ochrotomys nuttalli nuttalli*
Mouse, meadow jumping	*Zapus hudsonius americanus*
Muskrat, large-toothed	*Ondatra zibethicus macrodon*
Myotis, northern	*Myotis septentrionalis septentrionalis*
Nutria	*Myocastor coypus*
Opossum, Virginia	*Didelphis virginiana virginiana*
Pipistrelle, eastern	*Pipistrellus subflavus subflavus*
Raccoon	*Procyon lotor lotor*
Rat, black	*Rattus rattus rattus*
Rat, hispid cotton	*Sigmodon hispidus virginianus*
Rat, marsh rice	*Oryzomys palustris palustris*
Rat, Norway	*Rattus norvegicus norvegicus*
Shrew, Dismal Swamp short-tailed	*Blarina brevicauda telmalestes*
Shrew, least	*Cryptotis parva parva*
Shrew, pygmy	*Sorex hoyi winnemana*
Shrew, southeastern	*Sorex longirostris longirostris*
Shrew, southern short-tailed	*Blarina carolinensis carolinensis*
Skunk, striped	*Mephitis mephitis nigra*
Skunk, striped	*Mephitis mephitis mephitis*
Squirrel, eastern gray	*Sciurus carolinensis carolinensis*
Squirrel, southern flying	*Glaucomys volans volans*
Vole, dark meadow	*Microtus pennsylvanicus nigrans*
Vole, pine	*Microtus pinetorum scalopsoides*
Weasel, long-tailed	*Mustela frenata noveboracensis*

Source: VDGIF Online Database, 2010.

Table C-7. REPTILES AND AMPHIBIANS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Amphiuma, two-toed	*Amphiuma means*
Bullfrog, American	*Lithobates catesbeianus*
Frog, Brimley's chorus	*Pseudacris brimleyi*
Frog, coastal plain cricket	*Acris gryllus gryllus*
Frog, northern green	*Lithobates clamitans melanota*
Frog, southern leopard	*Lithobates sphenocephalus utricularius*
Newt, red-spotted	*Notophthalmus viridescens viridescens*
Peeper, northern spring	*Pseudacris crucifer crucifer*
Salamander, Atlantic Coast Slimy	*Plethodon chlorobryonis*
Salamander, eastern red-backed	*Plethodon cinereus*
Salamander, four-toed	*Hemidactylium scutatum*
Salamander, marbled	*Ambystoma opacum*
Salamander, northern dusky	*Desmognathus fuscus*
Salamander, southern dusky	*Desmognathus auriculatus*
Salamander, southern two-lined	*Eurycea cirrigera*
Salamander, three-lined	*Eurycea guttolineata*
Toad, eastern American	*Anaxyrus americanus americanus*
Toad, eastern narrow-mouthed	*Gastrophryne carolinensis*
Toad, Fowler's	*Anaxyrus fowleri*
Toad, southern	*Anaxyrus terrestris*
Treefrog, Cope's gray	*Hyla chrysoscelis*
Treefrog, green	*Hyla cinerea*
Treefrog, pine woods	*Hyla femoralis*
Treefrog, squirrel	*Hyla squirella*
Brownsnake, northern	*Storeria dekayi dekayi*
Cooter, Coastal Plain	*Pseudemys concinna floridana*
Cooter, northern red-bellied	*Pseudemys rubriventris*
Copperhead, northern	*Agkistrodon contortrix mokasen*
Cottonmouth, eastern	*Agkistrodon piscivorus piscivorus*
Earthsnake, eastern smooth	*Virginia valeriae valeriae*
Earthsnake, rough	*Virginia striatula*
Gartersnake, eastern	*Thamnophis sirtalis sirtalis*
Greensnake, northern rough	*Opheodrys aestivus aestivus*
Kingsnake, eastern	*Lampropeltis getula getula*
Lizard, eastern fence	*Sceloporus undulatus*
Milksnake, eastern	*Lampropeltis triangulum triangulum*
Racer, northern black	*Coluber constrictor constrictor*
Racerunner, eastern six-lined	*Aspidoscelis sexlineata sexlineata*
Ratsnake, eastern	*Pantherophis alleghaniensis*
Skink, broad-headed	*Plestiodon laticeps*
Skink, common five-lined	*Plestiodon fasciatus*
Skink, little brown	*Scincella lateralis*
Skink, southeastern five-lined	*Plestiodon inexpectatus*
Snake, northern red-bellied	*Storeria occipitomaculata occipitomaculata*
Snake, northern ring-necked	*Diadophis punctatus edwardsii*

Table C-7. REPTILES AND AMPHIBIANS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Snake, southern ring-necked	*Diadophis punctatus punctatus*
Stinkpot	Sternotherus odoratus
Turtle, eastern mud	Kinosternon subrubrum subrubrum
Turtle, eastern painted	Chrysemys picta picta
Turtle, eastern snapping	Chelydra serpentina serpentina
Turtle, striped mud	Kinosternon baurii
Watersnake, brown	Nerodia taxispilota
Watersnake, northern	Nerodia sipedon sipedon
Watersnake, red-bellied	Nerodia erythrogaster erythrogaster
Wormsnake, eastern	Carphophis amoenus amoenus

Source: VDGIF Online Database (latitude 36°51′59.7″ and longitude 76°03′ 54.9″), 2010.

Table C-8. INSECTS AND ARACHNIDS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

COMMON NAME	SCIENTIFIC NAME
Armyworm	*Pseudaletia unipuncta*
Borer, European corn	*Ostrinia nubilatis*
Butterfly, Aaron's skipper	*Poanes aaroni*
Butterfly, American copper	*Lycaena phlaeas*
Butterfly, American lady	*Vanessa virginiensis*
Butterfly, American snout	*Libytheana carinenta*
Butterfly, banded hairstreak	*Satyrium calanus*
Butterfly, black swallowtail	*Papilio polyxenes asterius*
Butterfly, Brazilian skipper	*Calpodes ethlius*
Butterfly, broad-winged skipper	*Poanes viator*
Butterfly, brown elfin	*Callophrys augustinus*
Butterfly, cabbage white	*Pieris rapae*
Butterfly, Carolina road-skipper	*Amblyscirtes carolina*
Butterfly, Carolina satyr	*Hermeuptychia sosybius*
Butterfly, checkered white	*Pontia protodice*
Butterfly, clouded skipper	*Lerema accius*
Butterfly, clouded sulphur	*Colias philodice*
Butterfly, cloudless sulphur	*Phoebis sennae eubule*
Butterfly, common buckeye	*Junonia coenia*
Butterfly, common checkered-skipper	*Pyrgus communis*
Butterfly, common sootywing	*Pholisora catullus*
Butterfly, common wood-nymph	*Cercyonis pegala*
Butterfly, confused cloudywing	*Thorybes confusis*
Butterfly, creole pearly-eye	*Enodia creola*
Butterfly, crossline skipper	*Polites origenes*
Butterfly, Delaware skipper	*Anatrytone logan*
Butterfly, Dion skipper	*Euphyes dion*
Butterfly, Dun skipper	*Euphyes vestris*
Butterfly, dusted skipper	*Atrytonopsis hianna*
Butterfly, eastern comma	*Polygonia comma*
Butterfly, eastern pine elfin	*Callophrys niphon*
Butterfly, eastern tailed-blue	*Everes comyntas*
Butterfly, eastern tiger swallowtail	*Papilio glaucus*
Butterfly, Eufala skipper	*Lerodea eufala*
Butterfly, falcate orangetip	*Anthocharis midea*
Butterfly, fiery skipper	*Hylephila phyleus*
Butterfly, gemmed satyr	*Cyllopsis gemma*
Butterfly, giant swallowtail	*Papilio cresphontes*

Table C-8. INSECTS AND ARACHNIDS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Butterfly, gray hairstreak	*Strymon melinus*
Butterfly, great purple hairstreak	*Atlides halesus*
Butterfly, great spangled fritillary	*Speyeria cybele*
Butterfly, gulf fritillary	*Agraulis vanillae nigrior*
Butterfly, Hayhurst's scallopwing	*Staphylus hayhurstii*
Butterfly, Henry's elfin	*Callophrys henrici*
Butterfly, hoary edge	*Achalarus lyciades*
Butterfly, Hobomok skipper	*Poanes hobomok*
Butterfly, Horace's duskywing	*Erynnis horatius*
Butterfly, Juvenal's duskywing	*Erynnis juvenalis*
Butterfly, lace-winged road-skipper	*Amblyscirtes aesculapius*
Butterfly, least skipper	*Ancyloxypha numitor*
Butterfly, little glassywing	*Pompeius verna*
Butterfly, little wood-satyr	*Megisto cymela*
Butterfly, little yellow	*Eurema lisa*
Butterfly, long-tailed skipper	*Urbanus proteus*
Butterfly, monarch	*Danaus plexippus*
Butterfly, mourning cloak	*Nymphalis antiopa*
Butterfly, northern broken dash	*Wallengrenia egeremet*
Butterfly, northern cloudywing	*Thorybes pylades*
Butterfly, Ocola skipper	*Panoquina ocola*
Butterfly, olive juniper hairstreak	*Callophrys gryneus gryneus*
Butterfly, orange sulphur	*Colias eurytheme*
Butterfly, painted lady	*Vanessa cardui*
Butterfly, Palamedes swallowtail	*Papilio palamedes*
Butterfly, pearl crescent	*Phyciodes tharos*
Butterfly, pipevine swallowtail	*Battus philenor*
Butterfly, question mark	*Polygonia interrogationis*
Butterfly, red admiral	*Vanessa atalanta*
Butterfly, red-banded hairstreak	*Calycopis cecrops*
Butterfly, red-spotted purple	*Limenitis arthemis astyanax*
Butterfly, reversed road-skipper	*Amblyscirtes reversa*
Butterfly, sachem	*Atalopedes campestris*
Butterfly, salt marsh skipper	*Panoquina panoquin*
Butterfly, silver-spotted skipper	*Epargyreus clarus*
Butterfly, sleepy duskywing	*Erynnis brizo*
Butterfly, sleepy orange	*Eurema nicippe*

Table C-8. INSECTS AND ARACHNIDS OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

COMMON NAME	SCIENTIFIC NAME
Butterfly, southern broken dash	*Wallengrenia otho*
Butterfly, southern cloudywing	*Thorybes bathyllus*
Butterfly, southern hairstreak	*Satyrium favonius*
Butterfly, southern pearly-eye	*Enodia portlandia*
Butterfly, spicebush swallowtail	*Papilio troilus*
Butterfly, spring azure	*Celastrina ladon*
Butterfly, striped hairstreak	*Satyrium liparops*
Butterfly, swarthy skipper	*Nastra lherminier*
Butterfly, tawny emperor	*Asterocampa clyton*
Butterfly, tawny-edged skipper	*Polites themistocles*
Butterfly, variegated fritillary	*Euptoieta claudia*
Butterfly, viceroy	*Limenitis archippus*
Butterfly, white M hairstreak	*Parrhasius m-album*
Butterfly, Yehl skipper	*Poanes yehl*
Butterfly, Zabulon skipper	*Poanes zabulon*
Butterfly, Zarucco duskywing	*Erynnis zarucco*
Butterfly, zebra swallowtail	*Eurytides marcellus*
Deerfly	*Chrysops vittatus vittatus*
Earworm, corn	*Heliathis zea*
Gnat	*Culicoides debipalpis*
Gnat	*Culicoides stellifer*
Moth, codling	*Cydia pomonella*
Moth, gypsy	*Lymantria dispar*
Moth, pinkstriped oakworm	*Anisota virginiensis*
Moth, sweetbay silk	*Callosamia securifera*
Tick, American dog	*Dermacentor variabilis*
Tick, brown dog	*Rhipicephalus sanguineus*
Tick, lone star	*Amblyomma americanum*
Tick, rabbit	*Haemaphysalis leporispalustris*
Tick, winter	*Dermacentor albipictus*

Source: VDGIF Online Database (latitude 36°51′59.7″ and longitude 76°03′ 54.9″), 2010.

Table C-9. THREATENED AND ENDANGERED SPECIES AND SPECIES OF SPECIAL OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

STATUS	COMMON NAME	SCIENTIFIC NAME
FE/SE	Woodpecker, red-cockaded	*Picoides borealis*
FE/SE	Tern, roseate	*Sterna dougallii dougallii*
FE/SE	Turtle, hawksbill (= carey) sea	*Eretmochelys imbricata*
FE/SE	Turtle, Kemp's (= Atlantic) Ridley sea	*Lepidochelys kempii*
FE/SE	Turtle, leatherback sea	*Dermochelys coriacea*
FT/ST	Turtle, loggerhead sea	*Caretta caretta*
FT/ST	Plover, piping	*Charadrius melodus*
FT/ST	Turtle, green sea	*Chelonia mydas*
SE	Turtle, eastern chicken	*Deirochelys reticularia reticularia*
SE	Plover, Wilson's	*Charadrius wilsonia*
SE	Bat, Rafinesque's eastern big-eared	*Corynorhinus rafinesquii macrotis*
SE	Rattlesnake, canebrake	*Crotalus horridus*
ST	Falcon, peregrine	*Falco peregrinus*
ST	Sandpiper, upland	*Bartramia longicauda*
ST	Shrike, loggerhead	*Lanius ludovicianus*
ST	Sparrow, Henslow's	*Ammodramus henslowii*
ST	Tern, gull-billed	*Sterna nilotica*
ST	Treefrog, barking	*Hyla gratiosa*
ST	Lizard, eastern glass	*Ophisaurus ventralis*
FS/ST	Eagle, bald	*Haliaeetus leucocephalus*
ST	Shrew, Dismal Swamp southeastern	*Sorex longirostris fisheri*
ST	Falcon, Arctic peregrine	*Falco peregrinus tundrius*
ST	Shrike, migrant loggerhead	*Lanius ludovicianus migrans*
FS	Spider, funnel-web	*Barronopsis jeffersi*
FS	Skipper, Duke's (or scarce swamp)	*Euphyes dukesi*
SS	Crossbill, red	*Loxia curvirostra*
SS	Sturgeon, Atlantic	*Acipenser oxyrinchus*
SS	Toad, oak	*Anaxyrus quercicus*
CC	Terrapin, northern diamond-backed	*Malaclemys terrapin terrapin*
SS	Heron, little blue	*Egretta caerulea caerulea*
SS	Owl, northern saw-whet	*Aegolius acadicus*
SS	Sparrow, saltmarsh sharp-tailed	*Ammodramus caudacutus*
SS	Tern, least	*Sterna antillarum*
SS	Warbler, Swainson's	*Limnothlypis swainsonii*
SS	Wren, winter	*Troglodytes troglodytes*
SS	Frog, carpenter	*Lithobates virgatipes*
CC	Turtle, spotted	*Clemmys guttata*
SS	Harrier, northern	*Circus cyaneus*
SS	Heron, tricolored	*Egretta tricolor*
SS	Ibis, glossy	*Plegadis falcinellus*
SS	Night-heron, yellow-crowned	*Nyctanassa violacea violacea*

Table C-9. THREATENED AND ENDANGERED SPECIES AND SPECIES OF SPECIAL OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET
(Cont'd)

STATUS	COMMON NAME	SCIENTIFIC NAME
SS	Owl, barn	*Tyto alba pratincola*
SS	Wren, sedge	*Cistothorus platensis*
SS	Creeper, brown	*Certhia americana*
SS	Tern, Forster's	*Sterna forsteri*
SS	Rabbit, marsh	*Sylvilagus palustris palustris*
SS	Dickcissel	*Spiza americana*
SS	Egret, great	*Ardea alba egretta*
SS	Finch, purple	*Carpodacus purpureus*
SS	Kinglet, golden-crowned	*Regulus satrapa*
SS	Moorhen, common	*Gallinula chloropus cachinnans*
SS	Nuthatch, red-breasted	*Sitta canadensis*
SS	Owl, long-eared	*Asio otus*
SS	Pelican, brown	*Pelecanus occidentalis carolinensis*
SS	Tern, Caspian	*Sterna caspia*
SS	Tern, sandwich	*Sterna sandvicensis acuflavidus*
SS	Thrush, hermit	*Catharus guttatus*
SS	Warbler, magnolia	*Dendroica magnolia*
SS	Mole, star-nosed	*Condylura cristata parva*
SS	Otter, northern river	*Lontra canadensis lataxina*

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010.

KEY - FE=Federal Endangered; FT=Federal Threatened; SE=State Endangered; ST=State Threatened; FP=Federal Proposed; FC=Federal Candidate; FS=Federal Species of Concern; SC=State Candidate; CC=Collection Concern; SS=State Special Concern DEP = Depleted status under the Marine Mammal Protection Act (*status is not listed by VDGIF).

Table C-10. SPECIES IDENTIFIED BY THE VIRGINIA WILDLIFE ACTION PLAN OCCURRING OR POTENTIALLY OCCURRING WITHIN 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET

TIER	COMMON NAME	SCIENTIFIC NAME
I	Woodpecker, red-cockaded	*Picoides borealis*
IV	Tern, roseate	*Sterna dougallii dougallii*
I	Turtle, loggerhead sea	*Caretta caretta*
I	Plover, piping	*Charadrius melodus*
I	Turtle, eastern chicken	*Deirochelys reticularia reticularia*
I	Plover, Wilson's	*Charadrius wilsonia*
I	Bat, Rafinesque's eastern big-eared	*Corynorhinus rafinesquii macrotis*
II	Rattlesnake, canebrake	*Crotalus horridus*
I	Falcon, peregrine	*Falco peregrinus*
I	Sandpiper, upland	*Bartramia longicauda*
I	Shrike, loggerhead	*Lanius ludovicianus*
I	Sparrow, Henslow's	*Ammodramus henslowii*
I	Tern, gull-billed	*Sterna nilotica*
II	Treefrog, barking	*Hyla gratiosa*
II	Lizard, eastern glass	*Ophisaurus ventralis*
II	Eagle, bald	*Haliaeetus leucocephalus*
IV	Shrew, Dismal Swamp southeastern	*Sorex longirostris fisheri*
II	Spider, Funnel-Web	*Barronopsis jeffersi*
III	Skipper, Duke's (or scarce swamp)	*Euphyes dukesi*
I	Crossbill, red	*Loxia curvirostra*
II	Sturgeon, Atlantic	*Acipenser oxyrinchus*
II	Toad, oak	*Anaxyrus quercicus*
II	Terrapin, northern diamond-backed	*Malaclemys terrapin terrapin*
II	Heron, little blue	*Egretta caerulea caerulea*
II	Owl, northern saw-whet	*Aegolius acadicus*
II	Sparrow, saltmarsh sharp-tailed	*Ammodramus caudacutus*
II	Tern, least	*Sterna antillarum*
II	Warbler, Swainson's	*Limnothlypis swainsonii*
II	Wren, winter	*Troglodytes troglodytes*
III	Frog, carpenter	*Lithobates virgatipes*
III	Turtle, spotted	*Clemmys guttata*
III	Harrier, northern	*Circus cyaneus*

Table C-10. SPECIES IDENTIFIED BY THE VIRGINIA WILDLIFE ACTION PLAN OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

TIER	COMMON NAME	SCIENTIFIC NAME
III	Heron, tricolored	*Egretta tricolor*
III	Ibis, glossy	*Plegadis falcinellus*
III	Night-heron, yellow-crowned	*Nyctanassa violacea violacea*
III	Owl, barn	*Tyto alba pratincola*
III	Wren, sedge	*Cistothorus platensis*
IV	Creeper, brown	*Certhia americana*
IV	Tern, Forster's	*Sterna forsteri*
IV	Rabbit, marsh	*Sylvilagus palustris palustris*
I	Rail, black	*Laterallus jamaicensis*
I	Sapsucker, yellow-bellied	*Sphyrapicus varius*
I	Warbler, black-throated green	*Dendroica virens*
I	Warbler, Wayne's	*Dendroica virens waynei*
II	Bittern, American	*Botaurus lentiginosus*
II	Duck, American black	*Anas rubripes*
II	Oystercatcher, American	*Haematopus palliatus*
II	Rail, king	*Rallus elegans*
II	Skimmer, black	*Rynchops niger*
II	Tern, royal	*Sterna maxima maximus*
II	Warbler, cerulean	*Dendroica cerulea*
III	Turtle, eastern box	*Terrapene carolina carolina*
III	Bittern, least	*Ixobrychus exilis exilis*
III	Brant	*Branta bernicla brota*
III	Night-heron, black-crowned	*Nycticorax nycticorax hoactii*
III	Redhead	*Aythya americana*
III	Sparrow, Nelson's sharp-tailed	*Ammodramus nelsoni*
III	Tern, common	*Sterna hirundo*
III	Mouse, Pungo white-footed	*Peromyscus leucopus easti*
III	Butterfly, Hessel's hairstreak	*Callophrys hesseli*
III	Butterfly, little metalmark	*Calephelis virginiensis*
III	Butterfly, mottled duskywing	*Erynnis martialis*
III	Butterfly, Palatka skipper	*Euphyes pilatka*
IV	Alewife	*Alosa pseudoharengus*
IV	Chubsucker, lake	*Erimyzon sucetta*
IV	Eel, American	*Anguilla rostrata*
IV	Shad, American	*Alosa sapidissima*
IV	Sunfish, banded	*Enneacanthus obesus*

Table C-10. SPECIES IDENTIFIED BY THE VIRGINIA WILDLIFE ACTION PLAN OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET
(Cont'd)

TIER	COMMON NAME	SCIENTIFIC NAME
IV	Sunfish, mud	*Acantharchus pomotis*
IV	Swampfish	*Chologaster cornuta*
IV	Frog, little grass	*Pseudacris ocularis*
IV	Salamander, eastern mud	*Pseudotriton montanus montanus*
IV	Salamander, many-lined	*Stereochilus marginatus*
IV	Siren, greater	*Siren lacertina*
IV	Spadefoot, eastern	*Scaphiopus holbrookii*
IV	Lizard, eastern slender glass	*Ophisaurus attenuatus longicaudus*
IV	Mudsnake, eastern	*Farancia abacura abacura*
IV	Ribbonsnake, common	*Thamnophis sauritus sauritus*
IV	Scarletsnake, northern	*Cemophora coccinea copei*
IV	Slider, yellow-bellied	*Trachemys scripta scripta*
IV	Snake, common rainbow	*Farancia erytrogramma erytrogramma*
IV	Snake, eastern hog-nosed	*Heterodon platirhinos*
IV	Blackbird, rusty	*Euphagus carolinus*
IV	Bobwhite, northern	*Colinus virginianus*
IV	Catbird, gray	*Dumetella carolinensis*
IV	Chat, yellow-breasted	*Icteria virens virens*
IV	Chuck-will's-widow	*Caprimulgus carolinensis*
IV	Cuckoo, yellow-billed	*Coccyzus americanus*
IV	Dowitcher, short-billed	*Limnodromus griseus*
IV	Dunlin	*Calidris alpina hudsonia*
IV	Flycatcher, willow	*Empidonax traillii*
IV	Godwit, Hudsonian	*Limosa haemastica*
IV	Godwit, marbled	*Limosa fedoa*
IV	Grebe, horned	*Podiceps auritus*
IV	Grosbeak, rose-breasted	*Pheucticus ludovicianus*
IV	Heron, green	*Butorides virescens*
IV	Kingbird, eastern	*Tyrannus tyrannus*
IV	Knot, red	*Calidris canutus rufus*
IV	Meadowlark, eastern	*Sturnella magna*
IV	Nuthatch, brown-headed	*Sitta pusilla*
IV	Ovenbird	*Seiurus aurocapilla*
IV	Parula, northern	*Parula americana*
IV	Pewee, eastern wood	*Contopus virens*
IV	Plover, black-bellied	*Pluvialis squatarola*

Table C-10. SPECIES IDENTIFIED BY THE VIRGINIA WILDLIFE ACTION PLAN OCCURRING OR POTENTIALLY OCCURRING WITHIN A 3 MILE RADIUS OF THE LYNNHAVEN RIVER INLET (Cont'd)

TIER	COMMON NAME	SCIENTIFIC NAME
IV	Rail, clapper	*Rallus longirostris crepitans*
IV	Rail, Virginia	*Rallus limicola*
IV	Rail, yellow	*Coturnicops noveboracensis*
IV	Sandpiper, purple	*Calidris maritima*
IV	Scaup, greater	*Aythya marila*
IV	Sparrow, field	*Spizella pusilla*
IV	Sparrow, grasshopper	*Ammodramus savannarum pratensis*
IV	Sparrow, seaside	*Ammodramus maritimus*
IV	Swallow, northern rough-winged	*Stelgidopteryx serripennis*
IV	Swift, chimney	*Chaetura pelagica*
IV	Tanager, scarlet	*Piranga olivacea*
IV	Thrasher, brown	*Toxostoma rufum*
IV	Thrush, Bicknell's	*Catharus bicknelli*
IV	Thrush, wood	*Hylocichla mustelina*
IV	Towhee, eastern	*Pipilo erythrophthalmus*
IV	Vireo, yellow-throated	*Vireo flavifrons*
IV	Warbler, black-and-white	*Mniotilta varia*
IV	Warbler, blue-winged	*Vermivora pinus*
IV	Warbler, Canada	*Wilsonia canadensis*
IV	Warbler, Kentucky	*Oporornis formosus*
IV	Warbler, prairie	*Dendroica discolor*
IV	Warbler, prothonotary	*Protonotaria citrea*
IV	Warbler, worm-eating	*Helmitheros vermivorus*
IV	Warbler, yellow	*Dendroica petechia*
IV	Waterthrush, Louisiana	*Seiurus motacilla*
IV	Whimbrel	*Numenius phaeopus*
IV	Whip-poor-will	*Caprimulgus vociferus*
IV	Woodcock, American	*Scolopax minor*
IV	Wren, marsh	*Cistothorus palustris*
IV	Lemming, southern bog	*Synaptomys cooperi helaletes*
IV	Mouse, cotton	*Peromyscus gossypinus gossypinus*
IV	Myotis, southeastern	*Myotis austroriparius*
IV	Butterfly, King's hairstreak	*Satyrium kingi*
IV	Butterfly, yucca giant-skipper	*Megathymus yuccae*

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010

KEY = Tier I - Critical Conservation Need; II=VA Wildlife Action Plan - Tier II - Very High Conservation Need; III=VA Wildlife Action Plan - Tier III - High Conservation Need; IV=VA Wildlife Action Plan - Tier IV - Moderate Conservation Need.

SECTION 404 (b) (1) EVALUATION

SECTION 404 (b) (1) EVALUATION
LYNNHAVEN RIVER ENVIRONMENTAL RESTORATION
VIRGINIA BEACH, VIRGINIA

I. INTRODUCTION

This report concerns measures proposed as part of the Lynnhaven River Environmental Restoration Feasibility Study as submitted in accordance with Section 404 of the Clean Water Act of 1977 (Public Law 95-217).

The 404(b)(1) guidelines in 40 CFR 230 contain the substantive criteria for evaluation of proposed discharges of dredged or fill material under Section 404. The principle behind the criteria is that no discharge of dredged or fill material is permitted that would result in unacceptable adverse effects to the aquatic ecosystem. Compliance with the guidelines is evaluated by reviewing the proposed discharge with respect to the four restrictions in 40 CFR 230.10. These restrictions state that:

a) No discharge shall be permitted if there is a practicable alternative which would have less adverse impacts on the aquatic ecosystem.
b) No discharge shall be permitted if it violates state water quality standards, violates toxic effluent standards or prohibitions under Section 307 of Act, or jeopardizes the continued existence of threatened or endangered species as identified under the Endangered Species Act of 1973.
c) No discharge shall be permitted which will cause or contribute to the significant degradation of waters of the United States.
d) No discharge shall be permitted unless appropriate and practicable steps have been taken to minimize potential adverse impacts to the aquatic ecosystem.

II. PROJECT DESCRIPTION

A. Location

The project area is situated entirely within the boundaries of the city of Virginia Beach, Virginia. The city is located approximately 100 miles from the state capital of Richmond, Virginia in southeastern Virginia. The Lynnhaven River Basin is a 64-square-mile tidal estuary in the lower Chesapeake Bay. Representing one-fourth of the area of the city of Virginia Beach, the watershed, is the largest tidal estuary in the city, lying within the heart of the urbanized northern half of Virginia Beach. The estuary is composed of three branches: the Eastern, Western, and Broad Bay/Linkhorn Bay.

Refer to the Draft Feasibility Report and Integrated Environmental Assessment (DEA) dated April 2013, for specific information regarding this project, environmental data, and maps and photographs of the project area.

B. Description of Proposed Work

The recommended plan includes four elements that were developed for the environmental restoration of the Lynnhaven River Basin. These are submerged aquatic vegetation (SAV) plantings, bay scallop restoration, construction of reef habitat, and restoration/diversification of wetland sites.

1. SAV Restoration

The restoration of SAV in the Lynnhaven River Basin will cover approximately 94 acres, 52.1 acres in Broad Bay and 41.7 acres in the main stem of the Lynnhaven. Selected sites will be planted with the seeds of two species, *Ruppia maritima,* widgeongrass, and *Zostera marina,* eelgrass. Seeds will be distributed from small boats, likely Carolina skiffs, which are usable in shallow water. Seeds may also be planted using divers or a mechanical planter operated off a small boat. Due to the greater environmental tolerances of widgeongrass, early efforts will be more focused on restoring it, though eelgrass will be attempted simultaneously in sites where it has the greatest chance for establishment. It is expected that the SAV beds established in the Lynnhaven River will be a mix of widgeongrass and eelgrass, with widgeongrass dominating. No fill material will be added to the Lynnhaven system during SAV restoration efforts.

2. Bay Scallop Restoration

Restoration of the bay scallop, *Argopecten irradians*, will occur at the SAV restoration sites one year after SAV seeding has been completed and the beds have been allowed to become established. The scallop restoration effort will consist of two techniques: 1. brood stock adults kept in cages to provide for maximum spawning efficiency and 2. juvenile and adult animals direct stocked within restored SAV beds. No fill material will be added to the Lynnhaven system during bay scallop restoration efforts.

3. Reef Habitat Construction

Restoration of reef habitat in the Lynnhaven River Basin will cover approximately 31.4 acres, with approximately 20.8 acres in Broad Bay and Linkhorn Bay. Additionally, 10.6 acres will be constructed in the main stem and Pleasure House Creek. Reef habitat will be created by placing concrete structures called "reef balls" onto the floor of the Lynnhaven system. At one site where the bottom substrate it too soft to support the reef structures alone, 6ft x 6ft geomesh mats filled with #3 railroad ballast stone will be placed beneath the reef balls in order to prevent the reef structures from sinking.

4. Salt Marsh Restoration/Diversification
Four sites have been identities for salt marsh restoration. At two wetland sites, Princess Anne (PA) and the Great Neck North Sites (GNN), *Phragmites australis*, an invasive wetland plant species, will be eliminated using both physical alteration of the site and chemical application. Within areas that are dominated by *P. australis* and can be accessed by heavy construction equipment, the *P. australis* stands will be first treated with an herbicide approved for wetland use in order to kill existing foliage. Then, approximately 2 to 4 feet of the upper peat layer will be excavated in order to remove as much *P. australis* material, including rhizomes, roots, and foliage, as possible to prevent recolonization. Features such as shallow pools, upland islands, and channels will be created to increase the diversity of the marsh habitat and to allow seawater to flood the area. Finally, clean fill will be added to adjust the elevation of the site, and the bare substrate will be planted with native marsh plants. Exclusion techniques will be used to protect the young plants from grazing by geese and other herbivores, while best practices will be used to stop erosion and to control sediment. In areas that cannot be reached with heavy equipment or where small patches of *P. australis* are present, aquatic herbicides will be applied either through aerial or manual application.

At the remaining two wetland sites, Mill Dam Creek (MDC) and Great Neck South (GNS), the "restoration" goals do not include the establishment of a *Spartina spp.* dominated salt marsh. Instead, the ecological function of the two sites will be improved through habitat "diversification." Habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous phragmites stands. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material. The material excavated from the tidal creeks and pools will be used to build upland mounts that will be planted with native shrubs or grasses. Some herbicide application may be necessary to kill phragmites rhizomes and foliage in the material used to create the upland mounds. Exclusion techniques will be used to protect the young plants from grazing by geese and other herbivores, while best practices will be used to stop erosion and to control sediment.

C. <u>Authority and Purpose</u>

This study is authorized by Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted May 6, 1998. The authorization states:

Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, that the Secretary of the Army is requested to review the report of the Chief of Engineers on the Lynnhaven Inlet, Bay and *connecting waters, Virginia, published as House Document 580, 80th Congress, 2nd Session, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of environmental restoration and protection and other related water resources purposes for the Lynnhaven River Basin, Virginia.*

D. General Description of Dredged or Fill Material

1. General Characteristics of Material

a. **SAV Restoration** – No fill material

b. **Bay Scallop Restoration** – No fill material

c. **Reef Habitat Construction** – The materials used to construction reef habitat are concrete reef balls of varying sizes. The reef balls used at for restoration would range in size approximately 2 feet in height and 3 feet in width to about 5 feet in width and 6 feet in height depending on the characteristics of each site.

At Site 8, located in Broad Bay Cove, the bottom substrate is made up of silt, clay, and silty sand and is judged to be too soft to support the reef balls. Mats of geomesh filled with #3 railroad ballast stone (between 1" to 2.5" in diameter) will be placed under each reef ball in order to prohibit the sinking of the structure into the sediment. The mats will be 6ft x 6ft in dimension.

d. **Salt Marsh Restoration/Diversification -** Material which is already on site will be excavated and used to create habitat features at two of the four wetland restoration sites (Mill Dam Creek and Great Neck South). At two of the restoration sites (Princess Anne and Great Neck North), the first 2-3 feet of substrate will be excavated from the marsh surface in order to remove the phragmites. This material will be removed from the project site and taken to an upland disposal area. Clean fill will be added to the site in order to attain an elevation optimal for the growth of native marsh plants.

2. Quantities of Material

a. **SAV Restoration -** No fill material

b. **Bay Scallop Restoration -** No fill material

c. Reef Habitat Construction – The estimated number of reef balls that will be placed at each site is listed in the table below.

		Number of Reef Balls			
Site		2'H X 3'W	4.3'H X5.5'W	4.5'H X 6'W	5'H X6'W
1		2428	-	-	-
2		13730	-	-	-
3		1928	-	-	-
4		3050	-	-	-
5		-	180	359	359
6		-	179	359	359
7		-	227	453	453
8	Normal Soil	-	358	715	715
	Soft Soil	-	1073	2146	2146
9		-	69	138	138

Approximately 75 percent of Site #8 consists of soft sediment, which will not support the weight of the concrete fish reefs. To ensure the stability of the reef balls, a 6ft x 6ft x 0.5 ft Geomesh mat, filled will #3 railroad ballast stone, will be placed under each reef ball. In total 5,365 concrete reef balls and mats will be placed on soft substrate in Broad Bay Cove. Each mat requires 0.67 yd^3 of stone, with a total of 3,577 yd^3 of stone necessary for the entire effort.

d. Salt Marsh Restoration/Diversification - The amount of material excavated and placed back on-site at the Mill Dam Creek site will be 600 cubic yards (CY), while 9,500 CY of material will be disturbed at the Great Neck South site. At the Princess Anne site, 26,500 CY of material will be excavated and removed from the site, and 2,000 CY of clean material will then be placed prior to replanting the area with native marsh plants. At Great Neck North, 1,900 CY will be excavated, with 2,000 CY of clean fill material brought onto the site.

3. Source of Material

Some material used at the wetland restoration sites will be excavated on-site and used to construct habitat features. Material obtained from the wetland sites will be tested for the presents of contaminants before it is excavated. If contaminants are found on-site, the material will not be disturbed. All new material to be used at the wetland sites and to build reef habitat will be obtained from commercial sources and will be free of contaminants.

E. General Description of the Discharge Sites

1. Location

a. **SAV Restoration** - No fill material

b. **Bay Scallop Restoration** - No fill material

c. **Reef Habitat Construction** – Nine sites within the Lynnhaven River Basin have been identified for the construction of reef habitat. These sites include approximately 31.4 acres of the Lynnhaven system. A list of the sites and their acreages are included in the table below.

Site	Location	Acres
1	Pleasure House Creek	1.21
2	Hill Point	6.87
3	Brown Cove	0.96
4	Brock Cove	1.53
5	Broad Bay North	1.79
6	Broad Bay North	1.79
7	Broad Bay Center	2.27
8	Broad Bay Cove	14.31
9	Linkhorn Bay	0.69

d. **Salt Marsh Restoration/Diversification** - All of the wetland sites are located in Virginia Beach, VA. The northern edge of the GNN site is defined by a bridge allowing Route 264/ Virginia Beach Expressway to cross the channel which connects the marsh to Linkhorn Bay. The southern limit of the site is established by Virginia Beach Boulevard. The GNS site is connected to GNN site via two, small culverts that run under Virginia Beach Boulevard. The PA site is located northeast of Virginia Beach Town Center in a highly developed area of the city. The northern edge of the MDC site is delineated by Mill Dam Road.

2. Size

The size of the Reef Habitat sites ranges from 0.69 to 14.31 acres. The specific areas are listed in the table above.

The GNN is the largest wetland site included in the Lynnhaven Restoration Project, consisting of 19.98 acres of tidal marsh, while the

MDC site is the smallest, with an area of 0.9 acres. The PA site is 3.82 acres in size and the GNS site includes 13.68 acres.

3. Type of Discharge Site

The Reef Habitat sites are subtidal areas within the Lynnhaven River with soft substrates. The wetland sites are areas of salt marsh that are located either intratidal or above the tide line.

4. Type of Aquatic Resources

The project area is located entirely within the Lynnhaven River Basin, which is the southernmost tributary to the Chesapeake Bay in Virginia. The Lynnhaven complex, which includes the mainstem, the Eastern Branch, the Western Branch, and the Broad Bay/Linkhorn Bay complex, is located in the city of Virginia Beach, along the southern shore of the Chesapeake Bay, between Cape Henry and the city of Norfolk. The basin occupies 64 square miles, which represents less than 0.4 percent of the area of Virginia and less than 0.2 percent of the Chesapeake Bay watershed. The river comprises over 5,000 acres of surface waters (VDEQ, 1999). The Lynnhaven River's major tributaries are London Bridge Creek (Eastern Branch), Wolfsnare Creek (Eastern Branch), Great Neck Creek (Eastern Branch), Thalia Creek (Western Branch), Buchanan Creek (Western Branch), and Pleasure House Creek. Land use in the basin is primarily residential.

This resource has 150 miles of shoreline and hundreds of acres of marsh, mudflat, and shallow water habitats. The river supports a tremendous level of recreational boating and fishing, crabbing, ecotourism, and general environmental observation. The navigational needs of the residents and users of the river are an integral part of the river's attraction. However, the river has become increasingly stressed, as the watershed has experienced a shift from a predominantly rural to a predominantly urban/suburban land use pattern. This conversion has subjected the river to the expected accompanying development pressures related to concurrent loss of natural buffers and increases in population and density.

5. Timing and Duration of Discharge

a. SAV Restoration – No fill material

b. Bay Scallop Restoration - No fill material

c. **Reef Habitat Construction** – Construction is expected to be completed in 24 months.

d. **Salt Marsh Restoration/Diversification** – The construction phase is expected to take 6 months at each site.

6. Description of Disposal Method

a. **SAV Restoration**
No fill material

b. **Bay Scallop Restoration**
No fill material

c. **Reef Habitat Construction**
A crane on a barge will be used to lower the reef balls into place on the river bottom. Underwater cameras will be used to monitor the positioning of the reef balls.

d. **Salt Marsh Restoration/Diversification**
The restoration and diversification of wetlands sites will require the use of excavation equipment to dig out the top layer of the marsh. This equipment will be used to either create habitat features at the GNS and MDC sites or load the material onto trucks to move it off site at the PA and GNN sites. Trucks and excavators will also be use to deliver clean fill to PA and GNN and then grade and contour the sites.

III. FACTUAL DETERMINATIONS

A. <u>Physical Substrate Determination</u>

1. Substrate Elevation and Slope

Less than 1 percent slope, with a 3-ft tidal range.

The SAV and scallop restoration efforts will not impact the elevation or slope present at those sites. Clean fill will be added to the GNN and PA sites in order to recreate the elevation necessary for the growth of native salt marsh plants. At the wetland sites where existing material will be used to create new habitat features (GNS and MDC), tiny changes in elevation will occur with the creation of channels, pools, and uplands. Reef balls will extend up to 5 ft in height; however, other naturally occurring structures and features from other restoration efforts currently within the system reach similar elevations.

6. Sediment type

a. **SAV Restoration** – N/A

b. **Bay Scallop Restoration** – N/A

c. **Reef Habitat Construction** -The substrate type present at each of the Reef sites is described in the table below.

Site ID	Location	Bottom Type	Description
EFH #1	Pleasure House Creek	SC	clayey sand
EFH #2	Hill Point	SP	poorly graded sand
EFH #3	Brock Cove	SC/SP	clayey sand/poorly graded sand
EFH #4	Brown Cove	CH/SC/SP	fat clay/clayey sand/poorly graded sand
EFH #5	Broad Bay	SW	well graded fine sand
EFH #6	Broad Bay	CH	fat clay
EFH #7	Broad Bay	CH/SP	fat clay/poorly graded sand
EFH #8	Broad Bay Cove	MH/CH/SM	high plasticity silt/fat clay/silty sand
EFH #9	Linkhorn Bay	SW	well graded fine sand

Concrete reef balls will be placed on the substrate at each reef site. For approximately 75 percent of the area of Site #8 the bottom substrate is too soft to support the weight of the reef ball. To support the reef structure, a 6ft x 6ft x 0.5 ft Geomesh mat fill with #3 railroad ballast stone will be placed under each reef ball.

a. Salt Marsh Restoration/Diversification – There will be no change in substrate type at GNS and MDC because the material used in the effort will come directly from the site. At the PA and GNN sites, clean, sand fill will be use to create a surface elevation optimal for the growth of native plants once the invasive plants have been removed. The material that is already on site includes sand, silt, peat, and other organic material.

3. Dredged/Fill Material Movement

a. SAV Restoration – N/A

b. Bay Scallop Restoration – N/A

c. Reef Habitat Construction – The reef balls are extremely large and heavy structures, weighing between 375 and 6,000 lbs. Each geomesh mat contains 0.67 CY of stone, weighing 1.2 tons each. The reef balls and geomesh mats will be moved to the reef site by barge and will be placed using a crane.

Once the mats and the reef balls are lowered into position, it is very unlikely that they will move out of position. Both the mats and the concrete balls are extremely heavy. Also, at sites where geomesh mats will not be used to support the reefs, the structures may sink slightly into the bottom substrate. The balls have flattened bottoms to further decrease the chances of the structures moving along the ocean floor.

d. Salt Marsh Restoration/Diversification - The sand fill that will be placed at the wetland sites will be planted with native salt marsh to prevent the fill from moving off-site. At sites where on-site material will be used to create new habitat upland features these areas will also be planted with native shrubs in order to keep the material in place. Best management practices will also be used to reduce the movement of fill material off-site.

4. Physical Effects on Benthos

The short term impacts to benthic communities would be both minor and temporary. Benthic invertebrates will be buried during the placement of geomesh mats and reef balls. Benthic organisms at the wetland sites will also be destroyed by construction activities. It is anticipated that losses to benthic populations will be quickly replaced. Benthic populations in areas adjoining project areas may be adversely affected by declines in water quality that will occur during construction; however, these impacts will last only during the construction phase, and normal conditions will return once construction has been completed.

5. Erosion and Accretion Patterns

No expected changes to erosion or accretion patterns will result from the reef habitat, bay scallop, or wetland elements of this project. SAV beds helps to stabilize the bottom over which they grow, preventing resuspension during tidal cycles and storm events, thus reducing erosion.

6. Actions Taken to Minimize Impacts.

Best management practices and reestablishment of vegetation would be used at the wetland sites during construction to minimize excess sedimentation during construction.

B. <u>Water Circulation, Fluctuation, and Salinity Determinations</u>

1. Water

a. **Salinity** – No effect

b. **Water Chemistry** – Minor and temporary effect on DO and biochemical oxygen demand during construction; temporary turbidity increase.

c. **Clarity** – Minor and temporary increase in turbidity will be generated during the construction phase.

d. **Color** – Minor and temporary change due to increase in turbidity.

e. **Odor** – Implementation of this project is not expected to alter odor levels.

f. **Taste**– Implementation of this project is not expected to alter water taste.

g. **Dissolved Gas Levels** – Minor and temporary decrease in DO during the construction phase.

h. **Nutrients** – Nutrient levels would increase during construction due to nutrients in disturbed soil sediment entering into the Lynnhaven River. Effects would be minor and temporary and levels would return to normal post-construction.

i. **Eutrophication** – The Lynnhaven River and surrounding wetlands would not become more eutrophic as a result of this project.

2. Current Patterns and Circulation.

a. **Current Patterns and Flow** – Reef habitat and SAV beds will cause changes; currents around reef structures and the grassbeds may be reduced from existing patterns. New channels will be built into the wetland sites, allowing increased tidal inundation.

b. **Velocity** – Changes, primarily reduction, due to wave and current energy baffling by SAV beds and reefs.

c. **Stratification** – No change.

d. **Hydrologic Regime** – Estuarine, no change.

e. **Aquifer Recharge** – No change.

3. Normal Water Level Fluctuations – No change.

4. **Salinity Gradients** – No change.

5. **Actions that will be taken to minimize impacts** – None.

C. **<u>Suspended Particulate/Turbidity Determinations.</u>**

1. **Suspended particulates and turbidity level**
Levels of suspended particulates and turbidity are expected to increase temporarily during construction. However, best management practices would minimize these effects. Turbidity is expected to return to normal levels soon after the completion of the project. Long-term improvements to suspended particulate and turbidity levels are a goal of the Lynnhaven Project.

2. **Effects on chemical and physical properties of the water column**

a. **Light Penetration** – Increased suspended solid particulate and turbidity levels would reduce light penetration in the Lynnhaven Basin during construction. Impacts will be temporary and short in duration. Best management practices would be employed during construction to minimize turbidity levels.

b. **Dissolved Oxygen** – Oxygen levels in the Lynnhaven Basin would be expected to decrease during construction due to increased suspended solids and turbidity, lowering the photosynthesis rate of aquatic vegetation. Levels would return to normal or improve following construction.

c. **Toxic Metals and Organics** – SAV, bay scallop stocking and reef habitat will have no impact on current levels of toxic metals and organics present in the Lynnhaven system. At the wetland sites, sediment will be tested prior to excavation to ensure that no contaminants are present in the material that will be disturbed. Commercial sources will be used for fill material used during the project to ensure that it is clean and without contaminants.

d. **Pathogens** – Fill materials will be clean and free of pathogens.

e. **Aesthetics** – SAV, bay scallop stocking, and reef habitat will have no impact on long term aesthetics. The aesthetic nature of the wetland sites would be reduced during construction with the removal of vegetation. Long term aesthetics may change with the restoration of the wetland sites.

3. Effects on Biota

a. Primary Production, Photosynthesis –Temporary increase in suspended solids during construction would reduce light transmission and photosynthesis. There will be no significant long term effects.

b. Suspension/Filter Feeders – Temporary increase in suspended solids during construction would impact suspension and filter feeders. Long term effects of the project would be extremely positive to these organisms. Reef habitat and SAV beds will produce new habitats, while scallop stocking would re-establish a self-sustaining population of bay scallops that is not currently present in the system.

c. Sight Feeders - Temporary increase in suspended solids and decrease in water clarity may impact hunting and foraging behaviors of sight feeders. Also, the use of heavy equipment during construction may disrupt normal behaviors by scaring sight feeders out of the immediate project site. These impacts should end once the construction phase has been completed. Long term effects of the project would be extremely positive to these organisms. Reef habitat and SAV construction would provide habitats that support sight feeder communities.

4. Action to Minimize Impacts.

Best management practices will be used at the wetland restoration sites in order to reduce the amount of disturbed sediment entering the aquatic system.

5. Contaminant determination.

No significant effects. The results indicated no significant contamination in the sediment or overlying water.

D. <u>Contaminant Determination</u>

1. **Evaluation of the Biological Availability of Possible Contaminants in the Fill Material**

   a. **Physical Characteristics of the Fill Material -** Fill material and concrete reef balls would be obtained from commercial sources. At the GNS wetland site, where material will be reused, a small number of commercial businesses surround the marsh, while the PA site is located in highly developed area for Virginia Beach. Although there is no suspected presence of contaminants, substrate disturbed at these sites will be tested for possible contaminants prior to construction activities.

   b. **Hydrography in Relation to Known or Suspected Sources of Contamination** – There are no suspected sources of contamination.

   c. **Results from Previous Testing of the Material or Similar Material in the Vicinity of the Project** – Sediment from the wetland sites have not yet been tested.

   d. **Known, Substantive Sources of Persistent Pesticides from Land Runoff or Percolation** – None found.

   e. **Spill Records for Petroleum Products or Designated Hazardous Substances** – Records investigation found no instances of spills in or around the project area.

   f. **Other Public Records of Significant Introduction of Contaminants from Industries, Municipalities or Other Sources** – Investigation of public record found no records of significant introductions of contaminants in or around the project area.

   g. **Known Existence of Substantial Deposits of Substances Which Could Be Released in Harmful Quantities by Man-Induced Discharges** – Investigation of public records found no instances of substantial deposits of harmful substances in or around the project site.

2. **Contaminant Determination**

An evaluation of the appropriate information above indicates that there is reason to believe the proposed fill material would not be a carrier of contaminants.

E. Aquatic Ecosystem and Organism Determinations

1. Effects on Plankton

Turbidity levels may temporarily affect plankton populations through abrasions by suspended material and light transmission reduction. However, these impacts would be minor and temporary.

2. Effects on Benthos

There will be a loss of benthos during the placement of reef habitat and construction efforts at the wetland sites. Relative to the entire system, losses resulting from the project will be small and temporary in nature. The long term goal of the project is to create benthic habitats (hard reefs and SAV beds) that are currently limited within the Lynnhaven Basin and it is anticipated that invertebrate organisms will quickly populate these areas. Stocking of bay scallops will re-establish a self-sustaining population of shellfish which has been lost to the system.

3. Effects on Nekton

Effects would be minor and temporary since it is anticipated that these species would move out of the work areas when construction begins and would return once the project is complete. Fish would derive long-term benefits from the creation of reef habitat, restoration of the wetland sites, and establishment of SAV beds.

4. Effects on Aquatic Food Web

Populations in the Lynnhaven River will be reduced during construction of reef habitat and at the wetland sites. Once work is completed, the aquatic food web would return to normal. The long term effects on the aquatic food web will be overwhelmingly positive, as new habitat types, which are currently limited within the system, are constructed.

5. Effects on Special Aquatic Sites

a. **Sanctuaries and Refuges** – A 52-acre oyster sanctuary, created by the US Army Corps of Engineers, is present in the Lynnhaven River Basin system. Construction of the Lynnhaven River Environmental Restoration Feasibility Project may have temporary impacts on the sanctuary due to increases in turbidity and suspended solids. However, these impacts will be temporary and conditions will return to normal once the construction phase has been completed.

b. **Wetlands** – Four wetland sites have been included in this project in order to either restore the native plant community or to increase habitat diversity. Excavation, grading, and equipment staging are planned for this area. However, these activities are necessary to improve the conditions at each site. At the PA and GNN sites, sediment and exotic plant material will be excavated from the area, and clean, sand fill will be added to the site in order attain an elevation that will support the growth of native marsh plants. The area will then be vegetated with salt marsh plants. At the GNS and MDC sites, marsh substrate will be excavated and then used to create new habitat features, such as tidal creeks, open pools, and wooded islands. These activities will initially disturb the marsh, but the long term effect of the action will increase habitat diversity at a site which is currently a monoculture of the invasive species, *Phragmites australis*. During project implementation, BMPs would be used to minimize the potential for release of fuels and other petroleum products and to reduce the input of sediment into the aquatic environment.

c. **Mudflats – No impact**

d. **Vegetated Shallows** – There are almost no SAV beds currently growing in the Lynnhaven System. The project may have temporary impacts on the existing SAV habitat due to increases in water turbidity during the construction phase. Water clarity will return to normal once the construction phase has been completed. The long term impact of the project on the vegetated shallows within the system will be positive, as 94 acres of SAV beds will be created.

e. **Riffle and Pool Complexes** - N/A

6. Effects on Threatened and Endangered Species

The Lynnhaven Project will have no negative impacts on federally threatened or endangered species. The proposed project will affect tidal salt marshes and shallow subtidal areas within the Lynnhaven Basin. The listed species documented as occurring or may potentially occur in the project area include five sea turtle species, one terrestrial bird, and two shore birds. The terrestrial bird, the pileated woodpecker, inhabits forested areas. The piping plover is associated with sandy beaches and does not utilize habitat types found at the proposed project sites. The roseate tern is a marine species that nests in colonies and plunge dives for fish. This bird could possibly use the subtidal sites as feeding grounds; however, this species prefer open ocean habitats. The Red Knot is a transient species which is known to fly through the project area in order to reach the species' major North Atlantic staging areas located in the Delaware Bay and Cape May Penisula. While sea turtles may forage in area of the proposed project, but they are highly mobile and would be able to avoid impacts from construction. One of the primary benefits of the Lynnhaven Restoration Project is the increase in secondary production, resulting in larger populations of prey items for sea turtles and shore bird species that utilize the project area.

7. **Effects on Other Wildlife**

Potential short term impacts associated with the Lynnhaven Project will occur during construction and include injury to aquatic fauna from direct encounters during the placement of the reef balls, burial under the reef balls, disruption of normal behaviors during the construction phase, and increased turbidity and suspended solids. These impacts would be minor and temporary, and conditions will return to pre-construction levels.

8. **Actions to Minimize Impacts**

The proposed material placement activities would be accomplished under conditions that would minimize, to the extent practicable, adverse effects on aquatic ecosystem. Best management practices would be employed during the construction at the wetland sites to avoid sedimentation. Specific actions include:

- Fills would be limited to the amount necessary to achieve project objectives.
- Fill material would be clean and free of contaminants
- An erosion control plan would be implemented to control the entry of sediments into streams and their migration downstream of the work areas.
- Fill material would be placed during low-tide, dewatered periods.

F. <u>Proposed Disposal Site Determinations</u>

1. **Mixing Zone Determination**

a. **Depth of Water at the Disposal Site** – Depth of water varies from 1 to 13 feet at the sites where the reef habitat will be constructed (see the table below). The depth of the wetland sites will be less than one foot.

Site Number	Depth (ft)
EFH #1	2 to 4
EFH #2	3 to 5
EFH #3	3 to 6
EFH #4	3 to 5
EFH #5	3 to 5
EFH #6	3 to 5
EFH #7	6 to 8
EFH #8	8 to 13
EFH #9	1 to 3

b. **Current Velocity** – Variable, the velocity within the Lynnhaven System is dependent on the tides.

c. **Degree of Turbulence** – Negligible

d. **Water Column Stratification** – Negligible

e. **Discharge Vessel Speed and Direction** – N/A

f. **Rate of Discharge** – N/A

g. **Dredged Material Characteristics** – The material that will be placed to construct reef habitat consists primarily of large concrete reef structures. At Site #8, geomesh mats, consisting of a plastic mesh that encapsulates clean, #3 railroad ballast stone, will be placed under the reefs.

The material used at the wetland sites will be either clean, sand fill or material that is already present at the wetland sites.

h. **Number of Discharges Per Unit of Time** – Discharges would occur at intervals throughout the construction period.

2. Disposal Site and Size

Due to the unique characteristics of the project, there will be no mixing zone. The construction of reef habitat involves the placement of large structures on the ocean floor. These structures will not mix with the bottom substrate. At the wetland sites, clean fill material will be placed in areas that are either intertidal during low tide or above the tidal range; therefore, no mixing will occur.

3. Actions to Minimize Adverse Discharge Effects

The proposed material placement activities would be accomplished under conditions that would minimize, to the extent practicable, adverse effects on aquatic ecosystem. Best management practices would be employed to avoid sedimentation. Specific actions include:

- Fills would be limited to the amount necessary to achieve project objectives.
- Fill material would be clean and free of contaminants.
- Fill material would be placed during low-tide, dewatered periods.
- An erosion control plan would be implemented to control the entry of sediments into streams and their migration downstream of the work areas.

4. Determination of Compliance with Applicable Water Quality Standards

The project will comply with all applicable water quality standards.

5. Potential Effects on Human Use Characteristics

a. **Municipal and Private Water Supply** – The proposed project would not affect municipal or private water supplies.

b. **Recreational and Commercial Fisheries** – A number of impacts of the project may affect the fisheries of the Lynnhaven Basin. These include short-term and minor turbidity increases, minor impacts to benthos, movement of nekton out of the area, and restriction of recreational and commercial activities at the project sites when construction equipment is in use to ensure public safety. These impacts will last through the construction phase. Long term impacts to the system will be overwhelmingly positive as the creation of reef habitat, re-establishment of SAV beds, and restoration/diversifications of wetlands will improve environmental conditions and benefit the finfish and shellfish populations within the Lynnhaven Basin.

c. **Water-Related Recreation** – Water-related recreation, such as boating and fishing, would be restricted in project areas during the construction phase to ensure public safety. Once the construction phase has been completed, water related recreation will return to normal.

d. **Aesthetics of the Aquatic Ecosystem** – Restoration of SAV and bay scallops and the construction of reef habitat would have no impact on the aesthetic quality of the Lynnhaven Basin. The aesthetic nature of the wetland sites would be reduced during construction when the current vegetation is removed to either be replaced by native salt marsh plants or to create new habitat features.

e. **Parks, National and Historical Monuments, National Seashores Wilderness Areas Research Sites, and similar Preserves** – No Impact.

G. **Determination of Cumulative Effects of the Aquatic Ecosystem**
There are many stressors on the aquatic system of the Lynnhaven River Basin. Overfishing, reduction in water quality, continuing development, and sea level rise are examples of some of these pressures that have negatively impacted the system and may continue to play a role in the stability and vitality of the resource. However, recent actions by the city of Virginia Beach, private organizations, and Federal agencies have resulted in improvements to water quality and environment of the Lynnhaven Basin. The Lynnhaven restoration project will act in conjunction with the continued efforts by these organizations to enhance to Lynnhaven River Basin ecosystem.

H. **Determination of Secondary Effects on Aquatic Ecosystems**
None anticipated.

III. FINDINGS OF COMPLIANCE OR NONCOMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE

A. Adoption of the Section 404(b)(1) Guidelines to this Evaluation

No significant adaptations of the guidelines were made relative to this evaluation.

B. Evaluation of the Availability of Practicable Alternatives to the Proposed Discharge Sites Which Would Have Less Adverse Impacts on the Aquatic Environment

A series of alternative of environmental restoration actions and features were developed and evaluated for feasibility. However, no other alternatives were found that would produce lesser adverse impacts on the aquatic environment.

C. Compliance with Applicable State Water Quality Standards

Fill activities have been coordinated with and are in conformance with the Commonwealth of Virginia standards. A 401 Water Quality Certification will be obtained from the Division of Water prior to construction.

D. Compliance with Applicable Toxic Effluent Standards or Prohibitions under Section 307 of the Clean Water Act

Section 307 of the Clean Water Act establishes limitation or prohibitions on the discharge materials containing certain toxic pollutants. The discharges associated with the proposed work would not contain these toxins, and, therefore, the project complies with Section 307.

E. Compliance with the Endangered Species Act of 1973

No threatened or endangered species or their critical habitat would be affected by the proposed project. This project complies with the stipulations of the Endangered Species Act.

F. Compliance with Specific Measures for Marine Sanctuaries Designated by the Marine Protection, Research, and Sanctuaries Act of 1972

Not applicable, the project does not involve the transportation or placement of dredged material in ocean waters pursuant to Sections 102 and 103 of the Act, respectively.

G. Evaluation of the Extent of Degradation of Waters of the United States

1. Significant Adverse Effects on Human Health and Welfare

a. **Municipal and Private Water Supplies** – The project would not affect municipal or private water supplies.

b. **Recreational or Commercial Fisheries** - Impacts to recreation and commercial fisheries will be minimal and temporary in nature.

c. **Plankton** – Adverse impacts will be minor and limited to the construction period.

d. **Fish** – Adverse impacts will be minor and limited to the construction period.

e. **Shellfish** – Adverse impacts will be minor and limited to the construction period.

f. **Wildlife -** Adverse impacts will be minor and limited to the construction period.

g. **Special Aquatic Sites** –Temporary adverse impacts to existing special aquatic sites in the Lynnhaven Basin are offset by predicted long-term benefits of environmental restoration.

2. Significant Adverse Effects on Life Stages of Aquatic Life and Other Wildlife Dependent on Aquatic Ecosystem

Direct and indirect negative impact to aquatic ecosystems would not be significant due to the project design and scope and measures taken to minimize impacts.

3. Significant Adverse Effect on Aquatic Ecosystem Diversity, Productivity, and Stability

The temporary and minor impacts which may result during the construction phase of the project will be minimal compared to the long term benefits that will be realized once the project has been completed. Implementation of the proposed project is expected to result in increases to diversity, productivity, and stability of the aquatic ecosystems.

4. Significant Adverse Effect on Recreational, Aesthetic, and Economic Values

Minor and temporary adverse effects to recreation and aesthetics are expected during the construction phase. These impacts will be eliminated once the construction phase has been completed. Long term impacts to recreation and aesthetics are expected to be overwhelmingly positive.

H. Appropriate and Practicable Steps Taken to Minimize Potential Adverse Impacts of the Discharge on the Aquatic Ecosystem

Appropriate steps to minimize potential adverse impacts from any discharges on aquatic systems have been incorporated.

I. Finding

The proposed discharges of fill material are specified as complying with the requirements of the 404(b)(1) Guidelines, with the inclusion of appropriate and practicable conditions as identified herein to minimize pollution or adverse effects on the aquatic ecosystem. These conditions will be attached and made part of the project record.

Approved by: ______________________________

Date: ______________________________

FISH AND WILDLIFE SERVICE PLANNING AID REPORT

FISH AND WILDLIFE SERVICE PLANNING AID REPORT

Lynnhaven River Basin Environmental Restoration Planning Aid Report

Prepared for:
U.S. Army Corps of Engineers
Norfolk District

Prepared by:
U.S. Fish and Wildlife Service
Virginia Field Office

December 2010

Introduction

The Norfolk District of the U.S. Army Corps of Engineers is conducting a feasibility study, authorized by the Water Resources Development Act (WRDA) of 1986, as amended by WRDA 1992, 1996 to determine whether planning efforts to improve water quality, environmental restoration and protection for the Lynnhaven River, Virginia should proceed. The Corps proposes to focus restoration in the following areas: 1) submerged aquatic vegetation (SAV), 2) reef habitat, 3) tidal wetland restoration and diversification, 4) establishment of a self-sustaining population of bay scallops (*Argopecten irradians concentricus*), and the restoariton of Fish House Island. This report provides general information on the existing baseline conditions, resources in the area, including endangered species, and evaluation of the potential project impacts. It is provided in accordance with provisions of the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) and the Fish and Wildlife Coordination Act (16 U.S.C. 661-667e, 48 Stat. 401) as amended.

Specific project details are as follows:

SAV Restoration

SAV restoration is targeted at twelve sites. Nine of the restoration sites are within the Lynnhaven Bay mainstem totaling 52 acres and three sites are in the Broad Bay/Linkhorn Bay complex totaling 42 acres. The restoration of SAV in the Lynnhaven River Basin will cover approximately 94 acres. There will be 52.1 acres in Broad Bay and 41.7 acres in the main stem of the Lynnhaven. The SAV sites will not be open to activities, such as oyster dredging or shelling for oyster reefs that could destroy the restoration project.

EFH Restoration

EFH will occur at nine sites which are divided by the different types of reef balls used. Restoration of EFH in the Lynnhaven River basin will cover approximately 31.4 acres, with approximately 20.8 acres in Broad Bay and Linkhorn Bay. Additionally, 10.6 acres would be constructed in the main stem and Pleasure House Creek. The main stem reef would consist of smaller "Bay" reef balls approximately 2-feet in height and 3-feet in width with 11-16 holes across the surface. Up to 2,000 "Bay" reef balls would be used in the main stem per acre.

The Broad Bay and Linkhorn Bay sites would consists of larger "Goliath", "Super" and "Ultra" reef balls. The "Goliath" reef balls are approximately 5-feet in height and 6-feet in width. The "Super" reef balls are approximately 4.5-feet in height and 6-feet in width. The "Ultra" reef balls are approximately 4.3-feet in width and 5.5-feet in height. The reefs would consist of 200 "Goliath", 200 "Super" and 100 "Ultra" reef balls per acre.

The reef sites would be open for recreational activities only. Commercial harvesting would not be allowed.

Wetlands Restoration

The wetlands restoration in the Lynnhaven River basin consists of two types of restoration, diversification of phragmites and eradication of the coomon reed (*Phragmites australis*). The Princess Anne (3.8 acres) and Great Neck North (19.9 acres) sites consist of eradication of phragmites with constructed tidal wetlands on site to replace it. The Mill Dam Creek (1 acre) and Great Neck South (13.7 acres) sites consist of diversification of the phragmites. The diversification of phragmites will be done by adding meandering channels, pools, and high marsh/upland areas. The high marsh will be constructed using the material excavated from the pools and channels created.

Bay Scallop Restoration

Restoration of the bay scallop will be done on the SAV sites one year after they are constructed. This will consist of holding them in racks at high density at several sites in the constructed SAV beds during the spawning season. Sites will be identified as source sites via hydrodynamic modeling. The SAV restoration sites will be permanent sanctuaries for the bay scallop.

Restoration of Fish House Island

Fish House Island is currently a 1.25 acre island near the mouth of the Lynnhaven Inlet. The restoration project will restore approximately 7.75 acres of salt marsh and high marsh habitat. The island will be protected by stone riprap and low sill breakwaters. It will not be available for public recreation.

Fish and Wildlife Resource Conditions

Threatened and Endangered Species

There are no federally listed threatened or endangered species that reside in the project area year round. However, transient species travel through the area include the piping plover (*Charadrius melodus*, LT), roseate tern (*Sterna dougallii dougallii*, LE), red knot (*Calidrus canutus rufa*, Candidate), and the shortnose sturgeon (*Acipenser brevirostrum*, LE). The piping plover is an uncommon summer resident in the lower Chesapeake Bay. They breed and forage in Virginia from March to October. The roseate tern used to breed on the Eastern Shore of Virginia barrier islands, but now would only be seen as they pass through the coastal area. Unpublished data indicate May and August are months in which the most sightings occur (Terwilliger et al. 1995). A roseate tern was last observed near the project area in 1981, approximately 700 feet north of Fish House Island. Red knots use the barrier islands along Virginia's Eastern Shore as a secondary staging area in the spring during their migration. The last reported observation of the shortnose sturgeon in the Chesapeake Bay was in 1998 in the Rappahannock River. Also, the species recently was reported in the Potomac River and it is believed to have passed through the Chesapeake Bay in order to reach the Potomac.

Sea turtle nesting falls under the jurisdiction of the U.S. Fish and Wildlife Service (Service) with respect to the ESA. The federally listed threatened loggerhead sea turtle (*Caretta caretta*), inhabits the continental shelves and estuarine environments along the margins of the Atlantic, Pacific, and Indian Oceans. On March 16, 2010 a proposed rule was published in the Federal Register to reclassify the loggerhead sea turtle through determination of the appropriate listing status for each of nine distinct populations of loggerhead sea turtle worldwide. Based on this proposed rule, the population affected by the proposed action is the north Atlantic population, and it is proposed for listing as endangered (72 FR 12598). Loggerhead sea turtles nest within the continental U.S. from Louisiana to Virginia. In Virginia, loggerhead sea turtles are found throughout the Chesapeake Bay, around the barrier islands off the Eastern Shore, and off the coast in the Atlantic Ocean, but nesting is limited to the Atlantic coastline, and nesting within the Chesapeake Bay is not known. The loggerhead is typically the only sea turtle that will nest as far north as Virginia. Loggerhead nesting in Virginia usually occurs from April through September. Females dig shallow pits on the beach to deposit their eggs. After hatching, hatchlings emerge and begin to crawl rapidly toward the ocean. Artificial lighting on the shoreline may disorient hatchlings and prevent them from safely reaching the water. The young can be found in Virginia waters from May through November of any given year. Although loggerheads nest in small numbers along Virginia's coast, there have been turtle nests along the Virginia Beach resort strip and in 2005 a federally listed threatened Green Sea turtle (*Chelonia mydas*) nested on Sandbridge Beach. A loggerhead sea turtle was observed in the mouth of Lynnhaven Inlet, approximately 1,000 north of the Fish House Island restoration site. There have been no reports of loggerheads nesting along the shoreline of the project site.

National Oceanic and Atmospheric Administration (NOAA) Fisheries has management responsibilities for threatened and endangered sea turtles when not on land. However, the Service has a vested interested in what affects sea turtles while at sea. The Chesapeake Bay is a foraging area for five species of sea turtles listed under the ESA. The loggerhead and the green sea turtle (*Chelonia mydas*) are listed as threatened, while the hawksbill (*Eretomchelys imbricata*), leatherback (*Dermochelys coriacea*), and the Kemp's ridley (*Lepidochelys kempii*) sea turtles are listed as endangered. All of these species are primarily oceanic but do forage within the Chesapeake Bay and nearshore Atlantic Ocean during the summer. The hawksbill and green turtles are infrequent in the Chesapeake Bay. The leatherback turtle is regularly found in the lower Bay during the summer in low numbers. Both juvenile loggerheads and Kemp's ridleys are found in relatively large numbers in the lower Bay. The Virginia Institute of Marine Science has conducted turtle surveys since 1979 in the Bay and estimates that up to 10,000 juvenile loggerheads and 500 to 700 Kemp's ridleys regularly use the Chesapeake Bay in the summer (Brown and Savitzky 1984). The turtles have been observed to forage primarily within the Chesapeake Bay proper. Loggerheads forage for benthic species, primarily horseshoe crabs and other shelled invertebrates, within the channels. Kemp's ridleys forage primarily in shallow areas and seagrass beds, feeding heavily on blue crabs.

Submerged Aquatic Vegetation

Preliminary results of the 2010 Virginia Institute of Marine Science (VIMS) SAV survey reported the presence of a 6.08 hectares SAV bed on the southern side of Broad Bay in the Lynnhaven River system (Figure 1; www.vims.edu/bio/sav/). The SAV density class was 0-10%. This bed was not reported in the 2009 survey but was reported in low numbers in the 2007 and 2008 surveys. Historically the Lynnhaven River supported SAV beds (www.vims.edu/bio/sav), which indicates the environmental conditions such as water clarity and substrate were appropriate for growth.

The SAV beds in the lower Chesapeake Bay are a mix of widgeon grass (*Ruppia maritima*) and eelgrass (*Zostera marina*), although eelgrass is the dominant species of SAV in the Chesapeake Bay. Eelgrass grows in distinct seasons. Maximum leaf biomass occurs in March and lasts until June. Minimal biomass occurs in August-September. The grass senesces at the end of June and growth slows during the winter months. Sexual reproduction begins in January and culminates in late May when seeds are released. One of the most important habitat criteria for SAV is water clarity because it affects the amount of light that reaches the plants. Other habitat conditions include water temperature, water depth, bottom sediment and wave action or turbulence. Many healthy SAV beds are situated behind sand bars due to the protection from turbulence the bar provides.

SAV beds provide important ecological roles for fish, blue crabs (*Callinectes sapidus*), waterfowl and infaunal species. Numerous studies have reported SAV bed use as refuge from predation by juvenile and adult finfish and shellfish (Orth et al. 1984, Rozas and Odum 1988, Ryer et al. 1990, Rooker et al. 1998). Juvenile fish such as striped bass (*Morone saxatilis*) will use SAV as a protective area until they grow out of their predator size range (Buckel and Stoner 2000), while blue crabs seek refuge in SAV beds when molting. SAV beds also act as nursery and settling areas for many species of drums (*Sciaenidae*) (Stoner 1983, Rooker et al. 1998) and juvenile blue crabs almost always are found in *Z. marina* beds (Perkins-Visser et al. 1996). It also plays an integral role in the life cycle of the bay scallop (*Aequipecten irradians*) by acting as a substrate on which the post-veliger larvae settle (Gutsell 1930, Connolly 1994, Irlandi 1996). SAV has been reported as the basis of the food chain by providing large amounts of detritus (Adams 1976, Bach et al. 1986). It also provides a direct food source for organisms higher in the food chain. Waterfowl such as the American wigeon (*Anas americana*), canvasback (*Aythya valisineria*) and green-winged teal (*Anas crecca*) feed on seeds and tubers during their fall and winter migration, where as others such as the redhead (*Aythya americana*) feed on the plant rhizomes. In addition, the infaunal community in SAV beds is distinct from unvegetated areas. There are increases in types of infaunal species and overall abundance inside SAV beds. The infaunal species increased sediment stability (Orth 1977) and food supply.

The Chesapeake Bay Program developed incremental measures of progress to approach SAV restoration in the Chesapeake Bay. The Tier 1 goal for the Lynnhaven River segment comprising the entire watershed is 71 acres and has not been met since aerial monitoring efforts were initiated in the 1970s. The Lynnhaven River contains ample restorable habitat for SAV due to its predominantly sandy substrate and shallow depths. However, because the SAV density is low and the Lynnhaven River is far from significant seed sources such that even if water quality permits, SAV is unlikely to re-establish itself in the project study area. In addition, in the Lynnhaven River, the extensive development of the local land mass caused extensive inputs of terrestrial sediments into the river basin, and are the primary cause of SAV declines in the river basin, and TSS levels in the water, along with eutrophication and slowly increasing water temperatures, all act along with a lack of a seed source to inhibit recovery (Cerco and Moore, 2001). Efforts have been initiated to restore this SAV via direct seeding of the shallow water habitat, and these efforts have been very successful (ERDC, 2008 – restoring eelgrass from seed: a comparison of planting methods for large-scale projects, Orth et al, 2006). These initial efforts indicate efforts towards the Chesapeake Bay Programs' SAV restoration goals area appropriate and feasible.

The mute swan (*Cygnus olor*) is a non-native ornamental waterfowl that was introduced in the 1800s. Since that time it has become established along the northeast Atlantic Coast and is one of four naturalized bird species that is considered invasive. The swans feed almost exclusively on submerged aquatic vegetation (Ciaranca et al. 1997). Fenwick (1983) determined that in the Chesapeake Bay, 81.8 percent of the mute swan diet consisted of SAV. He also calculated that males ate 34.6 percent of their body weight and females ate 43.4 percent of their body weight per day. Based on these numbers and the average body weight of a mute swan, the Service calculated that the current population of 3,6000 swans eats 10.5 million pounds of SAV from the Chesapeake Bay in a year (USFWS 2003). The quantity of SAV swans consume is not the only problem but also their behavior. The swans are sedentary with banded birds rarely moving more than 30 miles from their original banding location. Because of their sedentary behavior they can and will over-graze an area. Their grazing behavior is detrimental to the health of a SAV bed. The swans will consume immature seeds and uproot the entire plant instead of just eating the tops like other waterfowl.

SAV is protected by both state and Federal agencies. Federal agencies provide protection under Section 404 of the Clean Water Act (33 U.S.C. 1341-1987) and Section 10 of the Rivers and Harbors Act (33 U.S.C. 403), which regulate the discharge of dredged or fill material in the nation's wetlands and waters

Estuarine Fish/EFH

Anadromous fish, species that live in saline water and spawn in freshwater rivers, pass through the lower Chesapeake Bay area to reach their spawning and nursery grounds. These species include the Atlantic sturgeon (*Acipenser oxyrhynchus*), striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), blueback herring (*A. aestivalis*), alewife (*A. pseudoharengus*), gizzard shad (*Dorosoma cepedianum*), Atlantic herring (*Clupea harengus*) and white perch (*Morone americana*). The adults of these species enter the lower Chesapeake Bay area between February and April on their migration to their spawning grounds in the tidal Freshwater rivers.

Many species of finfish that spawn in the ocean or lower Chesapeake Bay utilize the estuary as a nursery area or as adults. Dominant species include: spot (*Leiostomas xanthurus*), Atlantic croaker (*Micropogonias undulatus*), Atlantic menhaden (*Brevoortia tyrannus*), weakfish (*Cynoscion regalis*), summer flounder (*Paralichthys dentatus*), bluefish *(Pomatomus saltatrix*), American eel (*Anguilla rostrata*), striped mullet (*Mugil cephalus*), silver perch *(Bairdiella chrysura*), black drum (*Pogonias cromis*), southern lungfish (*Menticirrhus americanus*), winter flounder (*Pseudopleuronectes americanus*), blue crab (*Callinectes sapidus*) and horseshoe crab (*Limulus polyphemus*).

NOAA Fisheries has designated areas in the lower Chesapeake Bay near the vicinity of the project area as Essential Fish Habitat (EFH) for many finfish species (Tables 1). Essential Fish Habitat is a designation that includes "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity". The designation was enacted in the 1996 amendment to the Fishery Conservation and Management Act of 1976 (90 Stat 331; 16 U.S.C. 1801 - 1882), as amended to preserve and conserve marine and estuarine habitat. The act requires Federal agencies to coordinate with NOAA Fisheries on all actions or proposed actions that may adversely affect EFH. For further information regarding consultation procedures, contact David O'Brian at the NOAA Fisheries office in Gloucester, Virginia (804-684-7228). General information on EFH can be obtained from; www.nero.nmfs.gov/ro/doc/newefh.html. Of particular importance is the identification of Habitat Areas of Particular Concern (HAPC). All borrow sites are within the vicinity of HAPC for the Sandbar shark (*Carcharhinus plumbeus*).

This area received this identification because it is an important nursery and pupping ground. Hard bottom 3-dimensional structures, reefs, are vital components in estuarine systems; they provide shelter, points of attachment for sessile organisms, and reduce water movement and energy. Reef habitat in estuaries generally consists of rocky bottom areas and in many regions, oyster reefs. In the Lynnhaven River, this habitat was historically oyster reefs, which in pre-colonial times were found both sub and inter-tidally throughout portions of the river where salinity levels were high enough to support oyster survival and growth. Today, most of these areas are either entirely lost (Chipman, 1948, Haven, 1979) or in some cases completely covered with considerable amounts of soft sediments (Dauer, pers. comm.). Extensive bottom surveys conducted in the course of oyster restoration planning (USACE, 2005) discovered two small (< 1 acre) natural oysters reefs, near the confluence of Lynnaven Bay and the western branch of the Lynnhaven River. These reefs were quite productive, containing approximately 250 adult oysters/square meter, indicating the subtidal hard substrate can still attract significant populations of oysters and other filter feeders, and in turn attract a wide variety of fin and shell fish species that utilize reef habitat.

Tidal Wetlands

Currently, the three of the four wetland restoration sites are almost exclusively dominated by common reed. Although some native plants are growing on the fringes of each site, specifically along the banks of the tidal creeks and along the borders of the uplands, the majority of these areas consist of dense, single-species stands of common reed. Tidal inundation is restricted to a large portion of each site. Sedimentation rates within common reed stands tend to be quite high, resulting in the decrease in water depths and the smoothing of the marsh surface. This process reduces the reach of sea water into the *Phragmites* stand, as compared to sites that are dominated by native plant species. In addition, two of the sites have been impounded due to roadways located at the head of the marsh. Small culverts are now the only connection that allows sea water to circulate into and out of the project sites. The current environmental conditions favor the continued growth of the common reed at these sites. If no action is taken, it is unlikely that site conditions will significantly change and the areas will continue to be comprised of dense monotypic stands of *P. australis*.

At the fourth site, large areas within the wetland are still comprised of indigenous salt marsh plants. However, *Phragmites* has begun to colonize areas within and surrounding the site. The marsh is not impounded, so there is little to no tidal restriction into the area. If no actions are taken, the areas adjacent to the tidal creeks that run through the site will remain vegetated with native species. However, in areas that have limited access to tidal flow the percentage of *P. australis* that makes up the plant community will increase until the invasive plant replaces the native species.

Bay scallops

Seaside lagoons once provided habitat for bay scallops until the 1930s when the habitat was destroyed by the "Storm King" hurricane (Seitz et al. 2009) and subsequent SAV die off. Since that time, scallops have not been present in the Lynnhaven Bay system or along other former habitat along Virginia's lower Eastern Shore. There are no scallop populations near enough to recruit to the area in any numbers. Left alone, it is unlikely scallops will recolonize the Lynnhaven Bay system River or any other nearby habitat.

Potential Biological Impacts

Endangered Species

Based on the project description, location, and the transient nature of federally listed species occupation of the area, we expect any federally listed species that approach the project area may avoid the vicinity during construction. Due to the expected avoidance behavior and low likelihood that federally listed species will be in the area during construction, we believe the affects of the project will be insignificant and discountable. Should project plans change or if additional information on the distribution of listed species or critical habitat becomes available, this determination may be reconsidered.

SAV

Once the widgeongrass is established, it should provide for more stable bottom and better water quality conditions conducive to the survival of eelgrass, which should then proliferate over a wider area. It is expected that the SAV beds established in the Lynnhaven River will be a mix of widgeongras and eelgrass, with widgeongrass dominating. Increasing SAV presence in the Lynnhaven system will provide nursery habitat and settling areas for many species of fish. SAV beds will also act as places of refuge, provide food sources, and when large enough, help dampen wave energy and slow shoreline erosion. The success of the SAV restoration will also dictate whether the Bay Scallops restoration efforts will succeed.

EFH

The installation of the reef balls may result in short term disturbance to motile species. We expect these species will avoid the reef balls as they are being lowered into the water and placed on the sediment. We expect long term impacts including burial and death to sessile species and slow moving motile species. These impacts will be limited to the footprint of the reef ball installed. Placement of the reef ball will stir up sedimentation that will impact near-by species. We expect impacts from sedimentation will be temporary and minor.

Long term impacts will primarily be beneficial to the aquatic species in the Lynnhaven Bay system. The reef balls will provide three-dimensional structure, which is currently limited. As mentioned above, these structures will provide shelter and points of attachment for sessile organism and egg masses.

Wetlands

Short term sedimentation will occur when grading the tidal marshes and creating habitat features. The earth disturbing activities will expose marsh sediment, which will create a higher erosion potential until the marsh plants become established. Motile species such as fish and birds that currently occupying the area will be temporarily displaced and fish will likely avoid the area during construction and subsequent sedimentation events. Sessile marsh species such as tidal plants and the Atlantic ribbed mussel (*Geukensia demissa*) or slow moving motile species, salt marsh periwinkles (Littoraria irrorata) will be up rooted, crushed, or buried. These impacts will be short term lasting the duration of the construction period.

Herbicide may kill non-targeted species if accidentally oversprayed or from drift. Adherence to spray conditions should minimize the risk.

In the long term the restoration should result in beneficial impacts to tidal marsh species inhabiting the sites and transient species that seasonally use the area. Restoration activities are also expected to attract a higher diversity of species and restore ecological function to the sites.

Bay Scallops

Few short term impacts are expected. We expect similar impacts from introducing the cages housing adult scallops as we described above from the installation of reef balls.

Long term affects of bay scallop reintroduction is increased water clarity and quality. Improved water conditions will provide positive benefits to other species in the system. We expect the SAV beds will expand, the planktonic food web will become more complex, and healthier conditions to other filter feeders. Bay scallops are a food source for aquatic predators, an increase in the scallop population will likely increase predator population levels.

Fish House Island

The short and long term impacts of the wetaland tidal marsh restoration are listed above. Short term impacts of building a breakwater would be the loss of benthos directly beneath the structure. However, the presence of breakwaters may create habitat for benthic species in the lee of the breakwater by reducing wave stress. The reduction in turbulence and shifting bottom may allow for the colonization of benthic species that cannot tolerate the current dynamic conditions. The actual breakwaters themselves will provide new structure for benthic organisms to colonize. The rocks that comprise the breakwaters will provide an attachment area for sessile organisms (Van Dolah et al. 1984). Some potential organisms that might colonize the breakwater structure include algae, barnacles, mussels, oysters, hydroids, bryozoans, and anemones. The interstitial spaces provide shelter for larger, motile organisms such as grass shrimp, mud and blue crabs, and a variety of small fish like blennies and gobies. The breakwaters may act as an artificial reef and attract larger fish since they house many prey species. Van Dolah et al. (1984) noted many recreationally and commercially important fish were attracted to the rocks after jetty construction. Although the construction of the breakwaters will negatively impact the benthic area directly beneath, it will create additional, dimensionally complex habitat.

Conclusion

The Service supports the Corps ecosystem restoration; the services provided from this project should increase the productivity of the Lynnhaven Bay system. We anticipate ecological benefits from the implementation of the project and thank you for the opportunity to coordinate with you.

Recommendations

$ The Service recommends monitoring wetland restoration sites to assess plant survival. Monitoring should occur frequently shortly after planting to determine if animal disturbance such as grazing will be a problem. If the site is being disturbed at such a level that will be detrimental to its success then additional protective measures should be considered. In addition, many contractors will provide a one-year guarantee that all plant material is healthy but do not specify who is responsible for monitoring for survival and if monitoring will be assessed following a specific protocol. If it is determined that re-planting is needed, the contract should guarantee the re-planted material for a year from when they are planted. The Service is also concerned about the potential for erosion and colonization by invasive species until the vegetation is established. A comprehensive monitoring program is needed to ensure the success of this restoration project.

$ Because the success of the Bay scallop restoration is contingent on successful SAV restoration, we recommend monitoring SAV health for a minimum of two years after restoration activities. Re-seed the SAV restoration sites if it does not meet the pre-established success criteria.

$ Aerial herbicide spraying should only be conducted if wind speeds are <5 miles per hour (mph). Wind direction is a lesser consideration because spraying will only occur at wind speeds of <5 mph. The likelihood of precipitation will should be considered when making the decision to spray. Weather forecasts and onsite conditions should be monitored before, during, and after spray operations. A chance of precipitation ≥30% within four hours prior to the start of spraying will result in a decision not to spray for that day. During herbicide treatment the wind speed and direction, aircraft speed, spray altitude, and spray mist/droplet size should be monitored continuously.

$ SAV restoration efforts could be hampered or negated by mute swans. Legislation HR 4114 is before Congress that proposes to remove protection of exotic species from the Migratory Bird Treaty Act. The Service recommends the mute swan population be monitored, and that the Corps work with the Service and the Virginia Department of Game and Inland Fisheries to develop a response plan if mute swans begin to negativity impact the restoration sites.

NMFS ESSENTIAL FISH HABITAT DESIGNATIONS

NMFS ESSENTIAL FISH HABITAT DESIGNATION

INTRODUCTION

This analysis includes the Essintial Fish Habitat (EFH) species that are found within the area of the proposed project. Each species summary includes a discussion of the life cycle and history of the animal, the status of the fishery, and how the animal will be affected by the proposed project.

Table 1. Summary of Essential Fish Habitat as designated by NOAA Fisheries for the Lynnhaven Inlet and Bay. The X indicates the lifestage for which this habitat is important.

Species	Eggs	Larvae	Juveniles	Adults
Red hake (*Urophycis chuss*)			X	X
Windowpane flounder (*Scopthalmus aquosus*)			X	X
Atlantic sea herring (*Clupea harengus*)				X
Bluefish (*Pomatomus saltatrix*)			X	X
Atlantic butterfish (*Peprilus triaccanthus*)	X	X	X	X
Summer flounder (*Paralicthys dentatus*)		X	X	X
Scup (*Stenotomus chrysops*)			X	X
Black sea bass (*Centrophristus striata*)			X	X
King mackerel (*Scomberomorus cavalla*)	X	X	X	X
Spanish mackerel (*Scomberomorus maculatus*)	X	X	X	X
Cobia (*Rachycentron canadum*)	X	X	X	X
Red drum (*Sciaenops occelatus*)	X	X	X	X
Sand tiger shark (*Odontaspis taurus*)		X		X
Atl.sharpnose shark (*Rizopriondon terraenovae)*				X
Dusky shark (*Charcharinus obscurus*)		X	X	
Sandbar shark (*Charcharinus plumbeus*)		HAPC	HACP	HACP

SANDBAR SHARK

Life Cycle and Habitat

This shark has designated HAPC (habitat area of particular concern) in the local area. This species is the principal species caught in the commercial shark fishery of the U.S. Atlantic coast and is also important recreationally (Conrath and Musick, 2007). It is a large coastal ranging species, with females growing up to 2.5 m and males up to 1.8 m total length. They typically roam in small groups or schools, segregated by sex, and undergo seasonal migrations to avoid overwintering in cold, northern waters. Due to this behavior, they range from Cape Cod to the western Gulf of Mexico, though they are not found north of the Carolinas in the winter months. Sandbar sharks, like many elasmobranch fishes, are viviparous, giving birth to live young. They typically give birth to less than 10 young, once per two years. The primary reason that the local waters are considered HAPC is because the lower Chesapeake Bay is one of the most important nursery grounds for this species on the U.S. East Coast. Female sharks give birth in the local area in large numbers, and the lower bay and lower Eastern Shore are important nursery grounds for the juveniles.

The Fisheries

The fishery is considered severely depleted. Restrictions on their take have been put in place to hopefully allow for species recovery. The status of the sandbar shark along much of the east coast is "protected," meaning that there is no permitted commercial harvest of the species in Federal waters but harvest does continue to occur in state waters under a quota set by National Marine Fisheries Service (NMFS). It does continue to be taken incidentally. Current numbers are low and do not support wide scale commercial fishing at this time.

SAND TIGER SHARK

Life Cycle and Habitat

This large shark can grow up to 3.9 meters in length and is usually found in sandy bottom coastal waters. It eats primarily fish, though squid and crustaceans are also consumed. They are found along the Atlantic coast but are not common in the local area.

They, like many elasmobranchs, give birth to live young; this species gives birth to only two young at a time and typically once every two years. Juveniles can be found in estuaries such as the Chesapeake Bay. It undergoes seasonal migrations, preferring cooler waters and migrating to cooler more northern waters in the summer. Its range in the northwest Atlantic Ocean is from the Gulf of Maine to the northern Gulf of Mexico.

The Fisheries

It is currently considered a prohibited species by NMFS and, if caught, must be released with minimal harm to the shark by both commercial and recreational fishermen. This is due to the severe declines in their numbers (> 90 percent) from heavy commercial fishing for this species in the 1980's and 1990's. Today, the species shows few signs of recovery and remains a species of concern (identified as a Species of Concern in 1997).

ATLANTIC SHARPNOSE SHARK

Life Cycle and Habitat

This small species, with a maximum size of 1.2 meters in length, ranges from the Carolina coast southward to the Gulf of Mexico year round, and ranging farther north to the Bay of Fundy, Canada, in warmer months. This fish typically inhabits shallow coastal and nearshore waters. It is a short lived shark species, typically living from 9-12 years. They feed on crustaceans, worms, small fish, and mollusks. They give birth to live young in a litter of 3-7 pups, usually in an estuary which is then the juvenile nursery area. In the Chesapeake Bay region, we are likely to only encounter adults as they typically pup further south.

The Fisheries

This shark is caught in commercial and recreational fisheries in the North Atlantic. Unlike many other shark species, however, it remains very abundant and is not currently at risk for being overfished.

DUSKY SHARK

Life Cycle and Habitat

The dusky shark is a larger species, growing up to 4 meters in length. The female dusky shark gives birth to live young, typically a litter of 6-14 pups. They usually reproduce every 3 years. This species typically eats fish, including smaller elasmobranchs such as other sharks, skates, and rays; though other prey, such as squid and sea turtles, are taken on occasion. In the North Atlantic, they range from George's Bank through the Gulf of Mexico, preferring warm temperature waters. Due to this temperature preference, more northern populations undergo seasonal migrations. Dusky sharks prefer oceanic salinities and are not commonly found in estuaries. It inhabits waters from the coast to the outer continental shelf and adjacent pelagic waters. It is not a common shark, and its slow reproductive rate makes it vulnerable to over exploitation.

The Fisheries

The dusky shark is a Species of Concern and is considered overfished. There was a commercial fishery for this species, and its large fins make it very valuable in the shark-fin trade. This fishery has since stopped due to lack of sharks, and the principal threat to population recovery is the recreational fishery for this species. Because of its late age at first reproduction (about 20 years) and its long time between births, this species is particularly vulnerable to overfishing.

RED HAKE

Life Cycle and Habitat

Red Hake can be found in the local area as juveniles and adults, though it would be uncommon in the Lynnhaven River due to its preference for oceanic waters, though they can be found, especially as juveniles, in the Chesapeake Bay mainstem during the cooler months of the year. The species occurs from North Carolina to southern Newfoundland. They are primarily a demersal fish and are found on or near the bottom. They spawn offshore through the summer and fall primarily, although eggs can be found in the water column almost year round. Eggs are typically found floating mostly at the edge of the continental shelf. Larvae are planktonic and feed mostly on zooplankton. They metamorphose into bottom dwelling juveniles. Juveniles use structure as cover, including reefs, sea scallops, depressessions in the sediments made by other fish, and other structures that provide any bottom relief. Adults are often found on or near the bottom, on reefs, or utilizing other structure, though they create their own depressions in the sea bottom for cover. They can also be found in the water column actively swimming at times. Adults prefer cooler waters of 2-22 °C.

The Fisheries

Red hake are managed as two U.S. stocks. The local stock is considered the southern stock, extending from southern Georges Bank to the Middle Atlantic Bight, the southern end of its range. The southern stock is currently considered overfished.

ATLANTIC SEA HERRING

Life Cycle and Habitat

Atlantic herring is a schooling, coastal, pelagic species ranging from Labrador to Cape Hatteras. The species undergoes extensive migrations for feeding, spawning, and overwintering. They lay demersal eggs throughout the late summer to early winter on any hard substrate, preferring gravel but also utilizing rocks, shells, or macophyte algae in areas with strong currents. Larvae are planktonic and can drift into estuarine waters during their developmental phase. Juveniles are pelagic and can be found in large schools in coastal waters in New England. Only adults are found in the local region, as spawning takes place in more northern, colder waters. Larvae, juveniles, and adults all feed on zooplankton. Adults are typically found in oceanic waters of at least 28ppt and are unlikely to ever be found in the Lynnhaven River system, though they can be found in Chesapeake Bay mainstem waters that approach full seawater salinity.

The Fisheries

The fishery is considered under utilized in its entirety, though the Gulf of Maine portion is considered fully exploited.

WINDOWPANE FLOUNDER

Life Cycle and Habitat

According to Essential Habitat Designations within the Northeast Region (Maine to Virginia), NOAA and NMFS describe habitat conditions for life stages of windowpane flounder. Eggs are found in surface waters around the perimeter of the Gulf of Maine, on Georges Bank, southern New England, and the middle Atlantic south to Cape Hatteras. Eggs are found where sea surface temperatures are less then 20 °C and water depths are less than 70 meters. In the middle Atlantic, eggs are often observed from February to November with peaks in May and October.

Juveniles are found in bottom habitats consisting of a mud or fine-grained sand substrate around the Gulf of Maine, on Georges Bank, southern New England, and the middle Atlantic south to Cape Hatteras. Juveniles are found in waters with temperatures below 25 °C, depths from 1-100 meters, and salinities between 5.5-36 ppt.

Adults are found in areas with bottom habitats consisting of mud or fine-grained sand around the perimeter of the Gulf of Maine, on Georges Bank, southern New England, and the Middle Atlantic south to the Virginia-North Carolina border. Adults are found in waters with temperatures below 26.8 °C, depths from 1-75 meters, and salinities between 5.5 and 36 parts per thousand (ppt). Spawning occurs in waters with temperatures below 21 °C, depths from 1-75 meters, and salinities between 5.5 to 36 ppt. Windowpane flounder are most often observed spawning during the months of February through December, with a peak in May in the middle Atlantic (NOAA/NMFS, 1999).

KING/SPANISH MACKEREL

The king mackerel, *Scomberomorus cavalla*, and Spanish mackerel, *Scomberomorus maculatus*, are members of the mackerel family, Scombridae. Both species support major commercial and sport fisheries along the Atlantic Ocean and Gulf of Mexico; their visits to the Chesapeake Bay are generally confined to the middle and lower Bay.

Life Cycle and Habitat

King mackerel inhabit coastal waters from the Gulf of Maine to Rio de Janeiro, Brazil, and the Gulf of Mexico, and they are most commonly found from the Chesapeake Bay southward and occasionally in the upper Bay. King mackerel are solitary surface dwellers that tend to be found near shore, often among reefs, wrecks, or other underwater structures. Immature fish school and sometimes mix with schools of Spanish mackerel of similar sizes. King mackerel are migratory in response to water temperature and prefer temperatures no lower than 68 °F.

King mackerel appear to spawn over a protracted period, with several peaks. On the Atlantic coast, larvae have been collected from May through October. Larval distribution indicates that spawning occurs in the western Atlantic off the Carolinas, Cape Canaveral, and Miami. There does not appear to be a well-defined area for spawning. King mackerel prefer to consume fish but also have been known to eat shrimp and squid. Female king mackerel can live for up to 14 years.

Spanish mackerel live in the coastal waters of the western Atlantic Ocean, from the Gulf of Maine to the Yucatan Peninsula. They are a schooling fish, preferring neritic, or shallow, ocean coastal waters, but they freely enter tidal estuaries. These mackerel are found most frequently in water temperatures between 70 and 88 °F and rarely in waters below 64 °F. Spanish mackerel is a common visitor to the middle and lower Chesapeake Bay from spring to autumn, sometimes swimming as far north as the mouth of the Patuxent River. Like the king, Spanish mackerel is a surface-dwelling, near shore species that will migrate over long distances in large schools along the shore. As water temperatures in the south increase, it moves north, entering the Chesapeake Bay when temperatures exceed 63 °F. They spawn off of the coast of Virginia between late spring and late summer. Spanish mackerel consume small fishes, shrimp, and squid, and reach a maximum age of 8 years.

The Fisheries

King mackerel support an important commercial fishery along the Gulf of Mexico and South Atlantic coasts. In recent years, they have primarily been caught commercially in south Florida and increasingly off North Carolina and Louisiana. Historically, there was a small commercial fishery for king mackerel in the Chesapeake Bay when pound nets and gill nets were introduced in the 1880's. Total commercial catch appears to have an average of 4 million pounds during the 1920's and 1930's. Commercial landings fell to 2.5 million pounds by the 1950's and increased to 8 million pounds in the mid-1970's. Since 1985, the coastal fishery has been quota managed, and catches have averaged 3.5 million pounds. Commercial landings of king mackerel in both Maryland and Virginia are insignificant, although in some years Virginia supports a small directed hook-and-line fishery.

The Spanish mackerel commercial fishery was born around 1850 along the Long Island and New Jersey coasts, and by the 1870s was well-established in the Mid-Atlantic and Chesapeake Bay area. In 1880, the Chesapeake Bay area produced 86 percent of the total coastal catch of 1.9 million pounds. By 1887, this number had dropped to 64 percent, after areas of major production changed. This trend continued, and from 1950 through 1985, Florida accounted for more than 92 percent of the Spanish mackerel commercial landings. Since 1986, Florida's contribution to the commercial harvest has decreased due to increased landings along the south and Mid-Atlantic. Total commercial landings ranged between 5 million pounds and 18 million pounds, and between 1950 and 1983 averaged around 8 million pounds. The coastal landings have been quota-managed since 1986 (Chesapeake Bay Program, 1999).

SUMMER FLOUNDER

Summer flounder or fluke (*Paralichthys dentatus*) live in estuarine and coastal waters from Nova Scotia to Southern Florida, with greatest abundance between Cape Cod, MA and Cape Hatteras, NC. Most summer flounder inhabit Chesapeake Bay in the summer and move offshore to depths of 120 to 600 feet of water during the fall and winter. However, some summer flounder over winter in the Chesapeake Bay. Flounder are more common in the deep channels of the lower Chesapeake Bay than in the upper Bay, extending as far north as the Gunpowder River.

Like other flounders, this species is a bottom-dwelling predator, relying on its flattened shape and ability to change color and pattern on the upper (eyed) side of its body. A predator with quick movements and sharp teeth, the flounder is able to capture the small fishes, squid, worms, shrimp, and other crustaceans that comprise the bulk of its diet. Summer flounder can live to 20 years of age with females living longer and growing larger than males (up to 95 cm total length [3ft]).

Life Cycle and Habitat

Summer flounder spawn during their offshore migration, from late summer to midwinter. Larvae and post-larvae drift and migrate in shore, aided by prevailing water currents, and enter the Chesapeake Bay from October through May. Larval flounder, which have body symmetry and eyes on both sides of their heads, more closely resemble the larvae of other fishes than they do adult flounder. Upon reaching the estuaries, larval flounder undergo a metamorphosis to the post-larval stage. During metamorphosis, the right eye of the larval flounder gradually migrates to the left side of the head–the feature distinguishing summer flounder from winter flounder, whose eyes are on the right side–and the body takes on the flattened appearance that it retains as an adult fish. Once the metamorphosis is complete, the post-larval flounder assumes the adults' bottom-dwelling lifestyle. Juvenile summer flounder often live among eelgrass beds in the Chesapeake Bay.

The Fisheries

Summer flounder are of major recreational and commercial importance north of Cape Hatteras. Anglers catch summer flounder from the shore, piers, and boats with hook and line. The recreational catch far exceeds the commercial catch in the Chesapeake Bay and near shore coastal waters. The lower Chesapeake Bay and seaside inlets produce the bulk of the recreational landings. Between 1979 and 1985, the combined recreational harvest in Maryland and Virginia averaged 5.5 million pounds per year, with 90 percent taken from Virginia waters.

Commercial landings in Virginia have historically been greater than those in Maryland. Between 1981 and 1986, Virginia averaged 5.7 million pounds per year and Maryland averaged 583,000 pounds. However, more than 90 percent of the landings recorded for both states have come from outside state waters. The great bulk of the catch is produced by the winter trawl fishery that operates in mid-continental shelf waters. In the Chesapeake Bay, summer flounder are commercially-caught by haul seines, pound nets, and gill nets, but the species does not form a significant commercial fishery. In 1990, only 48,000 pounds of summer flounder were taken in Virginia's Chesapeake Bay and ocean waters. Since the mid-1980's, commercial and recreational catches have declined precipitously because of overfishing and year-class failure. The Chesapeake Bay record for summer flounder is a fish weighing 15 pounds, which was taken in Maryland waters (Chesapeake Bay Program, 1999).

BLUEFISH

Bluefish, *Pomatomus saltatrix*, is the sole representative of the family Pomatomidae and is closely related to the jacks, pompanos, and roosterfish. Commonly known as chopper, tailor, snapper, elf, skipjack, greenfish, and blue, the bluefish inhabits the continental shelf waters of temperate zones. Along the eastern United States, it is found from Nova Scotia to Texas and visits the Chesapeake Bay region from spring to autumn. The bluefish is abundant in the lower Bay and common most years in the upper Chesapeake Bay, although it is rare north of Baltimore.

Life Cycle and Habitat

Schools of like-sized bluefish can cover tens of square miles and undertake extensive coastal migrations. Adults overwinter off the southeastern coast of Florida and begin a northerly migration in the spring, following warmer water with local movements into and out of bays and sounds. Their movement patterns are complex and not well understood. Younger fish appear to follow different migratory routes than older fish.

Bluefish have a worldwide distribution with occurrences recorded in the Atlantic Ocean, the Mediterranean Sea, the Black Sea, and the Indian Ocean. Adult bluefish are found in a variety of habitats, usually in response to food availability and spawning cues. Bluefish are voracious predators and will feed on virtually any food they can catch and swallow, including butterfish, menhaden, sand lances, silversides, mackerel anchovies, sardines, weakfish, spotted seatrout, croaker, spot, white perch, shad, alewife, blueback herring, and striped bass. Due to their predacious nature, bluefish are in competition with adult striped bass, mackerel, and large weakfish. They have few predators and can live 12 years and weigh up to 20 pounds.

During the northward migration, a spring spawning period occurs from Florida to southern North Carolina. A second spawning occurs off the Mid-Atlantic coast during the summer. In the Chesapeake Bay area, peak spawning is in July and occurs over the outer continental shelf. Most bluefish mature at age two and have high fecundity. Females can produce 900,000 to 4,500,000 eggs. The distribution of bluefish eggs is related to temperature and salinity and can vary from year to year.

Bluefish larvae can be found offshore between Cape Cod, MA, and Palm Beach, FL, during every season of the year. After the spring spawn, bluefish move shoreward. The smaller fish generally enter the Chesapeake Bay, while the larger fish head farther north. Larval distribution is affected by the wind and currents. Larvae that originate from spawning off the Chesapeake Bay are carried south and offshore. As larvae grow and are able to swim, they leave the surface for deeper water and move in shore. Early juveniles (young fish whose fins have formed) enter the lower Chesapeake Bay and its tributaries in the late summer and fall where estuarine areas provide food and shelter. In the early autumn, bluefish begin to migrate out of the Chesapeake Bay and move south along the coast. Peak abundance near the Chesapeake Bay mouth occurs from April to July and again in October and November.

The Fisheries

The bluefish commercial fishery in Chesapeake Bay accounts for about 20 percent of the total US landings of bluefish. Commercial landings from the Chesapeake Bay were generally high during the 1930's, modest to poor from the 1940's through the 1960's, and again high from the early 1970's through the mid-1980's. In recent years, overfishing has become a concern. Historically, the commercial bluefish harvest has been more important in Virginia than in Maryland, with 10 times the landings of Maryland.

The predominant commercial gear used in harvesting bluefish from the Chesapeake Bay has been pound nets but other gear also is used, including gill nets, otter trawls, haul seines, and hand lines. Currently, all commercial gears, except Virginia's hook and line fisheries, are required to have a license. The bluefish's aggressive feeding habits and spirited fight make it a popular and important sportfish. Landings from the recreational fishery are five to six times that of commercial landings. In the Chesapeake Bay, bluefish ranked highest in both number and weight among sportfish nearly every year from 1970 to 1990. Due to the high recreational value, the conservation effort by anglers has been strong (Chesapeake Bay Program, 1999).

RED DRUM

Red drum (*Sciaenops ocellatus*) is a member of the family Sciaenidae. Also known as channel bass, redfish, bull redfish, drum, puppy drum, and spottail, red drum is 1 of 13 species of sciaenids that occur in the Chesapeake Bay region. The family includes the commercially and recreationally important seatrouts, spot, croaker, kingfishes, silver perch, and black drum. The largest recorded red drum was 59 inches and 98 pounds, and the fish can live as long as 35 years.

Life Cycle and Habitat

Red drum are found from the Gulf of Maine to the northern coast of Mexico but are most commonly found south of the Chesapeake Bay. Adult red drum occur in the Chesapeake Bay from May through November and are abundant in the spring and fall near the Chesapeake Bay mouth. Adults travel in large schools often in near shore marine waters, but a red drum population extends as far north in the Chesapeake Bay as the Patuxent River. During mild winters, red drum may overwinter in the Chesapeake Bay, but they usually migrate seasonally, moving in schools offshore and southward in the winter and in shore to the north in the spring. Juvenile red drum also move from bays and estuaries to deeper waters of the ocean in response to dropping water temperatures in the fall and winter.

Male red drum begin maturing at age 1, while females mature at ages 4 to 5 in North Carolina and 2 to 3 farther south. Red drum are prolific spawners; large females are capable of producing nearly 2 million eggs in a single season. Spawning occurs in near shore coastal waters along beaches, and near inlets and passes from late summer and into the fall. Eggs spawned in the ocean are carried by currents into estuaries where they hatch.

Young-of-the-year appear in the estuary from August through September and newly hatched larval red drum are carried further by water currents toward fresher, shallower water. Juvenile drum in these areas feed on zooplankton and invertebrates such as small crabs and shrimp. Adults primarily feed on fish, crab, and shrimp.

The Fisheries

The commercial red drum fishery is not an important one in the Chesapeake Bay area. Virginia's commercial catch, once as high as 180,000 pounds per year, has been insignificant since 1965. Maryland's annual catch has not exceeded 2,000 pounds since 1954. Commercial landings of red drum baywide have been reported since the 1880s. The landings have varied widely, ranging from 4,400 pounds in 1973 to 1.7 million pounds in 1945. Landings in the Mid-Atlantic have declined since the 1930s. The fishery is generally nondirected, using pound-nets, shrimp trawls, hand lines, haul seines, and gill nets. Runaround gill nets were a dominant gear in Florida, taking 65 percent to 84 percent of the total catch, but that fishery has been closed due to concern that overfishing could cause stock collapse.

A modest recreational fishery exists. Most fish are taken by surf casting from seaside beaches and some by bait fishing along the Chesapeake Bay side of the lower Eastern Shore. The recreational fishery for red drum is a near shore fishery, targeting small "puppy drum" and large trophy fish. Trophy-size fish are caught along the mid- and south- Atlantic barrier islands, while smaller red drum are taken in shallow estuarine waters. The Chesapeake Bay size record is unknown, but the Virginia record is a fish weighing 85.3 pounds, which was taken from the seaside of Wreck Island in 1981. Since the 1980's the amount of fish caught for a given unit of effort has declined. Recreational catch peaked in 1984 at 9.96 million pounds.

Red drum on the Atlantic coast are managed jointly by the Atlantic States Marine Fisheries Commission (ASMFC) and the South Atlantic Fisheries Management Council (SAMFC). The commission wrote its Fisheries Management Plan (FMP) for Red Drum in 1984 and the council completed its own FMP in 1990. The Chesapeake Bay Program's FMP was completed in 1993. A serious problem in the fishery concerns intense fishing pressure on juvenile red drum in state waters, which results in significantly reduced recruitment to the spawning stock. Additionally, managers are concerned about the potential for a directed fishery outside state waters, which could directly reduce the spawning stock.

The goal for both the ASMFC and the SAMFC is to manage for sustained harvest by US fishermen, while maintaining the spawning stock biomass at 30 percent of the level that would occur with no fishing (30 percent SSBR). The objectives of the plans include: managing for 30 percent SSBR; providing a flexible management system that retains commission, council, and public input in the management process; and promoting cooperative research that will increase management decision making in the future. Research priorities for red drum are directed toward collecting the necessary data to perform an up-to-date stock assessment. This includes improved catch, effort and length/frequency statistics; increased data from night anglers; tagging of 3- to 5-year-old fish; standardized sampling of sub-adult fish; and developing an improved estimate of natural mortality (Chesapeake Bay Program, 1999).

COBIA

The cobia is the only species of the family *Rachycentridae* and is a migratory pelagic fish that is found in tropical, subtropical, and warm temperate waters throughout most of the world. However, they are not known to occur in the eastern Pacific. In the western Atlantic, they occur from Massachusetts and Bermuda to the Rio de la Plata of Argentina. They are seasonally common along the US coast from Virginia to Texas. Contrary to some earlier held beliefs, recent research has indicated that cobia frequenting US coastal waters maybe of a single genetic stock. This is supported by the fact that there is some movement between the Gulf of Mexico and Atlantic populations.

Life Cycle and Habitat

Cobia migrate north along the Atlantic coast from northern Florida to the Carolinas and then into the Chesapeake Bay by late May. Most fish depart Virginia coastal waters by late September/early October. However, it is unclear where cobia from the middle Atlantic US coast overwinter. Some findings suggest that after a southerly coastal migration, they may spend the winter on the outer half of the continental shelf. These movements are greatly affected by water temperature, with cobia entering the Chesapeake Bay after water temperatures exceed 67 °F. Adult cobia are coastal and continental shelf fish that occasionally enter estuaries. They may occur throughout the water column and over a variety of bottom habits including mud, rock, sand, and gravel; over coral reefs; in shore around pilings and buoys; and offshore around drifting and stationary objects.

Researchers believe the lower Chesapeake Bay may be an important spawning area. In Virginia, cobia are reported to spawn from late June through mid-August, with multiple spawnings in evidence. Eggs hatch within 36 hours of fertilization, with highest tank test hatching rates in water salinities of 33-35 ppt and a water temperature of approximately 79 °F. Female cobia appear to grow more rapidly and attain greater size than males. Females may reach maturity as early as 3 years of age at around 8 pounds and 28 inches. Some mature males have been noted at 2 years and 20 inches. Although some studies indicate the fish may live to upwards of 10 years, significantly more data is available on fish which have reached the age of 8 years: males average 42.5 inches and 33 pounds and females average 54 inches and 69 pounds. Of note, fish that weigh 45 pounds (minimum weight for Virginia Saltwater Fishing Tournament citations) are 5-6 year old females. The Virginia rod and reel state record cobia was a 103 pound (lb.), 8 ounce (oz.) fish caught in Mobjack Bay in 1980. While 114 lb. fish have been caught along the northern Gulf of Mexico coast, the world "all tackle" record is 135 lbs. 9 oz., recorded by an Australian angler in 1985.

To a large extent, cobia feed near the bottom, but they also take prey near the surface. They feed extensively on crabs and other crustaceans but also prey on other invertebrates and fish (Snider, 1996).

The Fisheries

Commercially, cobia have been an incidental catch in both hook-and-line and net fisheries, with the majority of fish taken from Gulf of Mexico waters. Research has also revealed there is a significant bycatch of cobia that occurs incidental to the bottom shrimp trawl fishery in the Gulf of Mexico. In the United States, recreational landings of cobia have not been historically well documented, although they have far exceeded commercial landings.

Recreational fishermen landed an estimated 216,000 cobia in US waters in 1965, while 119,000 were landed in 1970. During the period from 1984 through 1993, the number of fish caught along the Atlantic coast ranged from 29,199 in 1993 to 55,741 in 1992, with a yearly average of 37,521. The yearly average for this period in the Gulf of Mexico was 56,686. During the same period, the commercial catch in the Atlantic region ranged from 1,328 in 1985 to 6,078 in 1992, with a yearly average of 4,231. The yearly commercial average for the Gulf was 10,606.

Data on cobia landings in Virginia is sketchy at best. Figures from the VMRC depict the state commercial catch in pounds ranging from 545 lbs. in 1987 to 16,959 lbs. in 1990. Since 1993, any person desiring to catch and sell cobia in Virginia must possess a harvester registration card and a hook and line gear license. This requirement legally eliminates previous recreational fishermen who might have sold much of their catch.

In Virginia, as in most other states, the cobia is viewed primarily as a recreational fish. Fish receiving recognition in the state's Saltwater Fishing Tournament provide a barometer of the recreational catch in that they only reflect those fish over 45 lbs. (catch citation) and those over 48 inches (release citation implemented in 1991). The 300 citations each in 1962 and 1963 represent the largest numbers awarded prior to 1995. Between 1984 and 1995, the numbers ranged from 11 in 1984 to an unprecedented 603 in 1995 (Snider, 1996), with the number only slightly diminished in 1996 (Olney, 1998). Estimates of recreational catches are based on the NMFS Marine Fish Recreational Statistics Survey, which has not provided a consistently reliable reading of the Virginia catch (Snider, 1996).

In the US, the cobia is currently managed by the South Atlantic and Gulf of Mexico Fishery Management Councils. Although there is not a specific Cobia FMP, the species has been included within the FMP for Coastal Migratory Pelagic Resources. While most of the plan is dedicated to measures regarding king and Spanish mackerel, dolphin and cobia are also addressed (Snider, 1996).

BLACK SEA BASS

The black sea bass (*Centropristis striata*) is a member of the family Serranidae, or true sea basses. Also known in the Chesapeake Bay area as "black will," "chub," or simply sea bass, they are year-round inhabitants of the Mid-Atlantic region. These bass are bluish-black fish as adults and brownish as juveniles; they have scales with pale blue or white centers.

Life Cycle and Habitat

The black sea bass population extends from Maine to the Florida Keys and into the Gulf of Mexico. Black sea bass found north of Cape Hatteras are seasonally migratory and from a stock that is considered distinct from that south of the Cape. In the Chesapeake Bay, adults migrate offshore and south to overwinter in the deep, 100-meter waters off the Virginia and Maryland coasts. In spring the fish return to the mid and lower Chesapeake Bay, as far north as Solomon's Island, and remain there until late fall. Black sea bass have been captured as far north as the Chester River, but most fish encountered near the shore are juveniles (1 to 2 years old).

Adult black sea bass are considered a temperate reef fish and are most often found on rocky bottoms near pilings, wrecks, and jetties. Visual feeders during daylight hours, black sea bass rely on swift currents and their large mouths to capture their prey, which include other fish, crabs, mussels, and razor clams. Although they do not travel in schools, they can be found in large groups around structures or during in shore-offshore migrations.

Black sea bass are protogynous hermaphrodites, which means that initially they are females, but some larger fish (between 9 and 13 inches) reverse sex to become males. Thirty-eight percent of females in the Mid-Atlantic demonstrate sex reversal, usually between August and April, indicating that reversal takes place after spawning.

In the Mid-Atlantic continental shelf waters (59-148 ft deep), spawning begins in June, peaks in August, and continues through October. The fish, ages 2 to 5, produce approximately 280,000 eggs, which are buoyant and contain a single oil globule. Larvae develop in coastal waters 2 to 50 miles offshore at depths of up to 108 feet, preferring salinities of 30-35 ppt and temperatures of 58-82 °F. When they are about 13 milimeter (mm) (0.5 inches [in]), young black sea bass move in shore into estuaries, bays, and sounds, where they find shelter in beds of SAV, in oyster reefs, and among wharves, pilings, and other structures. Young black sea bass feed primarily on crustaceans, such as shrimp, amphipods, and isopods.

Juveniles migrate offshore in December, although some young-of-the-year may remain in the Chesapeake Bay throughout the winter. Black sea bass are reported to live as long as 20 years and reach a maximum adult size of two feet. However, individuals longer than 15 inches (approximately the size of an 8-year-old fish), are uncommon. Large fish are more common offshore than in the Chesapeake Bay.

The Fisheries

The black sea bass forms the base of an important recreational fishery. An estimated 1.5 million black sea bass were taken by anglers in the lower Chesapeake Bay in 1991. Anglers bottom fish using squid and other natural baits to catch this highly esteemed and flavorful fish. The commercial interest in the Chesapeake Bay is modest, however, with commercial landings averaging less than 2,275 kg (5,000 pounds) per year. Gear types include trawls, pots, and hook and line.

In 1996, the Chesapeake Bay Program developed the "Chesapeake Bay and Atlantic Coast Black Sea Bass Fishery Management Plan" to enhance and perpetuate black sea bass stocks in the Chesapeake Bay and its tributaries. Stock assessments before 1996 indicated that the species was being over-harvested in the Chesapeake Bay, which led the Mid-Atlantic Fishery Management Council/Atlantic States Marine Fisheries Commission to take several measures: implementing a 9-inch total length minimum size limit for 1996-97, with ensuing limits to be revised on an annual basis; requiring a 4-inch minimum mesh size for trawlers that harvest more than 100 pounds; and requiring all black sea bass pots to have escape vents and biodegradable hinges and fasteners. The goal is to reduce exploitation and to improve protection of the black sea bass spawning stock in the Chesapeake Bay and the Atlantic.

ATLANTIC BUTTERFISH

The Atlantic butterfish (*Peprilus triacanthus*) is a member of the family Stromateidae, of which two species are found within the Chesapeake Bay. Butterfishes are characterized as being very deep-bodied and highly compressed, with adults lacking pelvic fins (Murdy et al., 1997). The Atlantic butterfish is a fast-growing, schooling, pelagic fish that ranges from Newfoundland to the Gulf Coast of Florida, but is most abundant in the region from the Gulf of Maine to Cape Hatteras. It is a rather small fish, with maximum adult length reported as 30 centimeters (cm) (Murdy et al., 1997). Short-lived, butterfish rarely live beyond 3 years of age and attain sexual maturity at 1 to 2 years of age. Butterfish are typically found in euryhaline (5-32 ppt) environments (Musick, 1972).

Life Cycle and Habitat

Butterfish occur in large schools in bays and over continental shelves. They are a pelagic species, typically found in waters over shallow bottoms. The butterfish occurs in the Chesapeake Bay from March through November and is considered common to abundant in the lower bay. Within the bay, the butterfish move northward in the spring, first appearing in Virginia waters in March but not found above the Rappahannock River before May. All leave the bay by December, overwintering offshore in deeper water (590-690 feet) (Murdy et al., 1997).

Butterfish are broadcast spawners, and spawn offshore from May to July in the Chesapeake Bay. After hatching, juveniles move into the near-coastal waters, sometimes including bays and estuaries. The young often hide from predators in mats of floating seaweed or among the tentacles of jellyfish. Juveniles feed primarily on phytoplankton, while the adult diet is comprised mainly of jellyfish, small fishes, crustaceans, and worms. (Murdy et al., 1997).

The Fisheries

The butterfish fishery of the Chesapeake Bay is presently of minor commercial importance. Formerly, catches were much larger. For example, in 1920, Chesapeake Bay landings were reported as 590,000 kilograms (kg) (1.3 million pounds), with almost all catch from pound-nets. In contrast, the reported catch for 1990 was 9,100 kg (20,000 pounds). Catches occur in two peaks, the first occurring from April-May and the second occurring from September-October. Butterfish are of only minor interest to recreational fishermen, as they rarely take bait (Murdy et al., 1997). The butterfish stock is not overfished nor approaching an overfished condition (Cross et al., 1999; NMFS, 1997).

CLEAR NOSE SKATE

Life History and Habitat

This small elasmobranch skate occurs in the North Atlantic ranging from Nova Scotia to the Gulf of Mexico, though it is rare in the northern portion of its range and migrates from cooler northern waters as winter approaches. It is migratory in the local area, typically appearing in the Chesapeake Bay in April to November-December. In the Bay, the only records have been from the Bay mainstem; none have been caught in the tributaries. The maximum size is approximately 80 cm total length at an age of 5-6 years. They feed on small benthic organisms as well as on small fishes. Typical habitat is softer bottom areas along the continental shelf, though they can also be found in rockier habitat. As is common in skates, this species is an egg layer, typically laying up to 30 pairs of eggs in a season. Both juveniles and adults can be found in the Chesapeake Bay. They prefer higher salinity waters of > 22 ppt, with most being found in waters of at least 31 ppt.

The Fisheries

There is a commercial fishery for the clear nose skate. The primary means to capture them is via otter trawling, though they are also taken as bycatch in groundfish trawling and scallop dredging fisheries. This small species is typically used for bait, not human consumption. The current status is not overfished.

WINTER SKATE

Life History and Habitat

This small elasmobranch skate occurs from the coast of Newfoundland to Cape Hatteras. It prefers colder waters than many fish species found in the Chesapeake Bay area. In the local area, it can be found from December to April. Its maximum size is approximately 1.5 m in total length. Similar to most skates, it is an egg layer. It is not known to lay eggs in the local area, preferring colder waters to spawn in, and juveniles are not commonly found in the Chesapeake Bay area, only rarely being observed near the Bay mouth in the winter. It typically feeds on a wide variety of invertebrate benthic organisms but also takes small fish and squid. It prefers sand and gravel bottoms but can sometimes be found on mud bottom habitat. It typically buries itself in the sand during the day, feeding at night.

The Fisheries

Otter trawling is the main method to catch most skate species, including the winter skate. This species is also caught as bycatch during groundfish trawling and during sea scallop dredging. The skate fishery is mainly a bait fishery, though this larger species does have a commercial market for its wing meat for human consumption. As a result of these uses, fishing pressure grew intense and the winter skate was overfished. However, it has since recovered and although its biomass is still well below its original level (about 25 percent of the observed peak) and it is not currently considered to be overfished.

LITTLE SKATE

Life History and Habitat

This is a small elasmobranch species, and adult maximum size is approximately 60 cm. It occurs from Nova Scotia to Cape Hatteras and is very abundant. Like most skates, it is an egg layer and has been known to lay eggs throughout the year. This skate typically feeds upon small invertebrates, primarily crustaceans, squid, and polychates, though fish and other organisms are sometimes consumed. They prefer sand or gravel bottoms, as do many skate species, though they can also be found on mud bottom habitat. The often bury themselves in the sand during the day and feed at night.

The Fisheries

There is a commercial fishery for the clear nose skate. The primary means to capture them is via otter trawling, though they are also taken as bycatch in groundfish trawling and scallop dredging fisheries. This small species is typically used for bait, not human consumption. The current status is not overfished, and the population biomass is estimated to be a medium level.

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ADAPTIVE MANAGEMENT PLAN

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INTRODUCTION

Project Description

The study area consists of the entire Lynnhaven River Basin, which is located in the city of Virginia Beach, Virginia. The Lynnhaven River, with its three branches (the Eastern, Western, and Broad Bay/Linkhorn Bay) encompasses an area of land and water surface that is approximately 64 square miles in area. The watershed, representing one-fourth of the city of Virginia Beach, is the largest tidal estuary in the city and lies in the heart of the urbanized northern half of Virginia Beach. This basin has 150 miles of shoreline and hundreds of acres of marsh, mudflat, and shallow water habitats. The river supports a tremendous level of recreational boating, fishing, crabbing, ecotourism, and general environmental observation. However, the river has become increasingly stressed as the watershed has shifted from predominantly rural to predominantly urban/suburban. Changes resulting from development of the surrounding uplands, such as loss of natural buffers, more impervious surfaces, and increases in population and density, have impaired the ecosystem within the river.

The Lynnhaven River Basin Restoration study identified specific areas of concern that must be addressed in order to restore environmental function and quality to the system. These areas of concern are reduced water quality, loss of tidal wetlands, loss of submerged aquatic vegetation (SAV), and the amount of siltation occurring in the system. The recommended plan developed by the United States Army Corps of Engineers (USACE) for the environmental restoration of the Lynnhaven River Basin is made up of four elements. These elements are SAV plantings, bay scallop restoration, construction of fish reefs, and restoration and diversification of wetland sites.

Fish Reefs in the Lynnhaven River Basin will cover approximately 31.4 acres, with approximately 20.8 acres in Broad Bay and Linkhorn Bay. Additionally, 10.6 acres will be constructed in the main stem and Pleasure House Creek. Fish Reefs will be created by placing concrete structures called of various types onto the floor of the Lynnhaven system, producing artificial, hard reef habitat. At sites where the bottom substrate it too soft to support the reef structures, geomesh mats filled with stone will be place beneath them to prevent the structures from sinking into the substrate.

Submerged Aquatic Vegetation Restoration-The restoration of SAV in the Lynnhaven River Basin will cover approximately 94 acres: 52.1 acres in Broad Bay and 41.7 acres in the main stem of the Lynnhaven. Selected sites will be planted with SAV seeds of two species, widgeon grass *(Ruppia maritime)* and eelgrass (*Zostera marina*). Seeds will be distributed using small boats, likely Carolina skiffs, which are usable in shallow water. The seeds may also be planted using divers, or mechanical planters, operated off a small boat. Due to the greater environmental tolerances of widgeon grass, early efforts will be focused on restoring this species, though eelgrass will be attempted simultaneously in sites where it has the greatest chance for establishment. It is expected that the SAV beds established in the Lynnhaven River will be a mix of widgeon grass and eelgrass, with widgeon grass dominating.

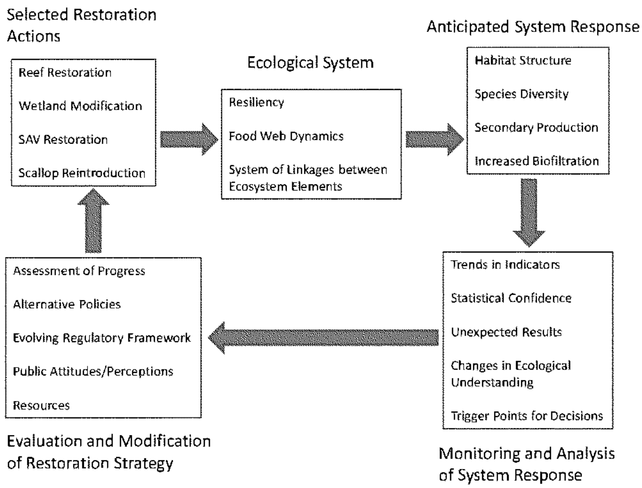
Bay Scallop Restoration-Restoration of the bay scallop will occur at the SAV restoration sites one year after SAV seeding has been completed and the beds have been allowed to become established. The scallop restoration effort will consist of two techniques; first, juveniles and adults will be direct stocked within restored SAV beds, and then brood stock adults will be kept in cages to provide maximum spawning efficiency.

Salt Marsh Restoration and Diversification-At two of the wetland sites, Princess Anne (PA) and the Great Neck North Sites (GNN), the population of the invasive plant species, common reed (*Phragmites australis*), will be eliminated using both physical alteration of the site and chemical application, and a indigenous salt marsh community will be established. Within areas that are dominated by *P. australis* and can be accessed by heavy construction equipment, the *P. australis* stands will be first treated with an herbicide approved for wetland use in order to kill existing foliage. Then, approximately 2 to 4 feet of the upper peat layer will be excavated in order to remove as much *P. australis* material, including rhizomes, roots, and foliage, as possible to prevent recolonization. Features such as shallow pools, upland islands, and channels will be created to increase the diversity of the marsh habitat and to allow seawater to flood the area. Finally, clean fill will be added to adjust the elevation of the site, and the bare substrate will be planted with native marsh plants. In areas that cannot be reached with heavy equipment or where small patches of *P. australis* are present, aquatic herbicides will be applied either through aerial or manual application.

The "Restoration" goals proposed for the Mill Dam Creek (MDC) and Great Neck South (GNS) sites do not include the establishment of a *Spartina spp.* dominated salt marsh. Instead, the ecological function of the two sites will be improved through habitat "diversification." Habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous phragmites stands. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material. The material excavated from the tidal creeks and pools will be used to build upland mounts that will be planted with native shrubs or grasses. Some herbicide application may be necessary to kill phragmites rhizomes and foliage in the material used to create the upland mounds.

Adaptive Management

In order to adequately address the uncertainties inherent in a large environmental project and to improve the performance of the project, Adaptive Management (AM) has recently been developed and adopted by the USACE. AM replaces dependency on numerical models and traditional planning guidelines which were used in the past to manage the unpredictability of complex environmental projects and, instead, applies a focused "learning-by-doing" approach to decision-making. The "learning-by-doing" approach is proactive – it is an iterative and deliberate process using the principles of scientific investigation. Through a program of regular monitoring that allows a better understanding of the ecosystem and the projects place in the system, a project's design and operation are continuously refined. Information that can guide a project adaptive management plan (AMP) can include results from scientific research and monitoring, new or updated modeling information, and input from managers and the public. Potential applications of this "learning by doing" AM approach include: (1) transfer of lessons learned from one program/project to another to avoid pitfalls; (2) use of physical models/modeling to test possible outcomes of management decisions; and (3) incorporation of flexibility and versatility into project design and implementation. The basic process works as follows:



This AMP describes how the project elements of the Lynnhaven Restoration Project will be monitored and adjusted if long term monitoring finds adverse impacts on the native populations or if the project elements are not providing the benefits predicted in the integrated report. It describes the process for evaluating the results of the monitoring program, "triggers" or action points that would necessitate modifications to the project, and potential changes that would be implemented to improve the performance of the project. The monitoring program should accomplish the following:

- It should support *adaptive management* decisions by providing data on critical stages in the development of the reefs, scallops, SAV and wetlands that can guide the next steps in the restoration process. This monitoring should answer crucial questions that affect implementation decisions. For example: Did sufficient numbers of transplanted scallops survive and spawn to support continued stock development? Is the biomass on the reefs increasing? Are reef-dependent fish utilizing the reefs? Are the diversified wetlands maintaining the native vegetation along the re-graded contours or is it being re-invaded by Phragmites?

- It should evaluate intermediate conditions that help to *track progress* toward the final goals. For instance, are enhanced abundances of scallop larvae and new recruits observed in a tributary following seeding with broodstock? Are newly-seeded SAV beds increasing in shoot density per unit area of SAV bed annually? Is biomass increasing on the reefs on an annual basis as predicted? Such a monitoring objective permits setting *intermediate goals* and evaluating success in reaching those goals.

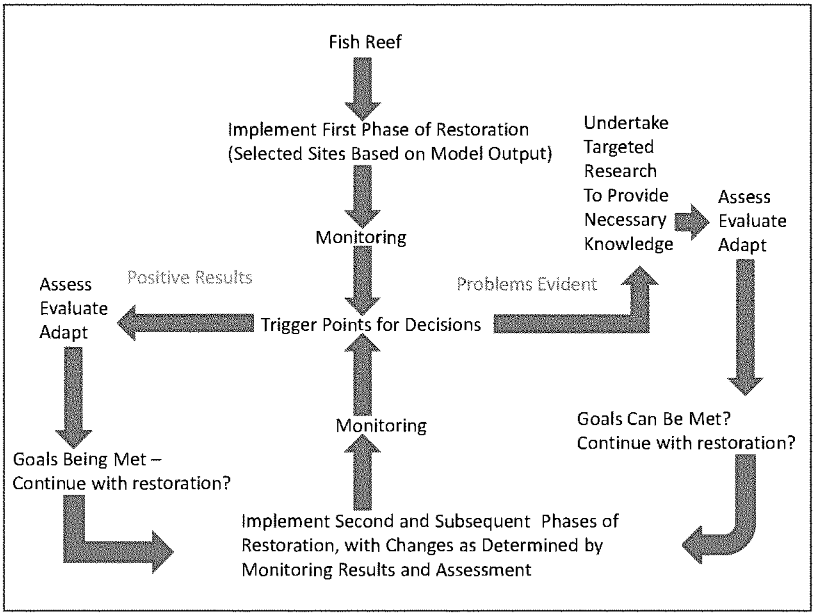
- It should measure specific elements necessary to evaluate *success criteria* established for the project. For instance, numbers and sizes of oysters and other sessile filter feeders are needed to evaluate the secondary production and filtration capacity of a restored multiple-use reef as proposed in the plan.

- It should aid in *identifying unexpected stresses*, environmental conditions, and/or ecological interactions that can affect the overall success of the project. For instance, water quality, particularly temperature, TSS and chlA, can be affected by a very wide range of factors; measuring all of which would be impractical, but having a monitoring program in place that could recognize when water quality problems affected the success of a project would be invaluable. Major storm events during periods where there are planktonic larvae of sessile filter feeders can significantly and negatively influence subsequent recruitment, which will result in lower than desired secondary production by the reefs. Droughts, on the other hand, can produce better conditions for recruitment.

As discussed in the risk analysis section, the risk varies with each project element, with scallop restoration having the highest risk, SAV moderate risk, and the fish reefs and wetlands diversification the lowest risk.

ESSENTIAL FISH HABITAT

Once placed, fish reefs should need little intervention due to their durability. Due to the size of the project, though, there are opportunities to employ AM as the project will be phased in over a period of several years. The numbers of reef structures necessary will take several deployments prior to the settling season (spring-summer) of local sessile and reef-dependent species. Several types of structures should be placed, as current available research does not identify which one is best for local use. The basic reef AM process is as follows:



The first sites implemented will be based on prior model output and were identified as important source-sink areas for recruitment of oysters and other sessile life-forms that have a planktonic phase (Lipcius et al. 2008), with potential smaller-scale deployments in other areas if the leases are obtained and the bottom freed for use for the fish reefs.

Monitoring

The fish reefs will need to be assessed annually for up to 10 years post placement to determine the health of the sessile benthic community that grows upon them and also to determine nekton usage. The first five years will likely be annual, and if the reefs appear to be on track to reach desired secondary production levels, bi-or tri-ennial monitoring can begin. Such surveys could include direct monitoring by divers on the reefs and taking samples on and around the base of the reefs in order to determine the species composition, biomass, and growth rates of the biota on the reefs. This might also be performed by raising a small number of reef structures to the surface for sampling, along with benthic bottom grabs near the reef base. Further actions could include use of a remotely operated underwater vehicle (ROV) or stationary cameras to take video to document fish use in and around the reefs, as well as to examine the reefs themselves. Such a technique is less invasive than direct sampling. Random sampling on a small sub-set of reef structures at each proposed reef site will be necessary for a complete monitoring program. Sufficient samples will be taken to keep the SE (standard error) within 25% of the mean (average) value. For oyster reef restoration projects, which these reefs are similar to, this will require approximately 30-60 samples from the entire reef complex which includes all sites and types of structures throughout the river (not 30-60 per reef site). This should ensure sufficient statistical confidence in the results to clearly see trends in indicators to allow for proper documentation of project objectives and goals, as well as to decide whether or not to implement any adaptive management measures. The main management trigger point is secondary production, which is annualized for the reefs. The following table shows the expected values over time. Failure to meet at a minimum 50% of the desired number of these annual metrics will require re-visiting the project implementation schedule and construction plan, as well as possible the goals and expectations for the project. The need to conduct additional research to attempt to determine why goals are not being met will also be considered. Such information could result in modifications of subsequent deployments.

Reef Secondary Production Over Time, High and (Low) Relief Reef

Year	Secondary Production (kg/acre/year) for high and low (in parenthesis) reef habitat
0*	223 (180)
1	446 (360)
2	891 (720)

3	1783 (1440)
4	2897 (2341)
5	4457 (3601)

*assumes deployment prior to first settling season no later than April with first monitoring results for year 0 obtained from a fall survey. If deployment is later year 0 should be moved to one year later.

Other indicators that should be documented are the presence of reef-dependent fish utilizing the reef structures as well as the species composition of the sessile and motile organisms living on the reef structures, which can be used to estimate increases in BIBI from the pre-construction conditions. While the species composition can be calculated during the physical sampling of the reefs, the reef fish assessment is recommended to be done using underwater video. If such species are not observed, credit for their secondary production should be re-assessed (Peterson et al. 2003) and downgraded, as it is part of the goal metric secondary production. Small reef dependent species such as gobies, blennies, toadfish and clingfish should be observable on the reef. Larger structure using species, such as black sea bass, sheepshead, tautog, gag grouper, spottail pinfish, silversides, sheepshead minnow, pigfish, cobia, black drum, and others should also be observed utilizing the constructed reef habitat. From the video, record should be made of fish species observed and approximations of their numbers. If this proves insufficient, fish traps or other means to obtain physical samples should be considered. The other major component of the enhanced secondary production is an expected increase in blue crab and other crustacean production. Fishing records for blue crabs can be consulted to see if there is an increase in the area of the reefs, or if fishery independent data is desired, a separate study could be undertaken to assess blue crab density within the reef areas by comparing them to a sandy bottom open area without such structure.

The estimated costs for this monitoring and associated documentation will be $40,000 per year. Extensive monitoring at this level would be needed for the first five-ten years post construction. Ten years is needed for this option due to the large number of reef structures and the need to collect sufficient samples over a longer period of time than other options. The proposed reefs will likely take longer to mature than five years as a variety of species that use the reefs have longer life cycles, such as many of the larger reef-dependent fish species. Additionally, it is important to determine how long oysters and other shellfish survive on the reefs. In the past, oysters could live for up to 25 years and given the documented disease resistance of the Lynnhaven oyster population, a lifespan greater than five years may now be possible and it is important to document this. After that, assuming the reefs have matured, a smaller effort, primarily using a ROV, could be implemented at a lower cost of $10,000 per year, and done once every 2-3 years. This effort would be supported by the local sponsor, as after the initial 10 years the USACE will close out the project and all monitoring (including the fish reefs, wetlands, SAV and scallops) will be the responsibility of the local sponsor, the City of Virginia Beach. Monitoring will be done by specialists with the subject matter expertise necessary to design and conduct the monitoring. These will likely be scientists from regional universities with published work and research relevant to the restoration effort.

Adaptive Management

Due to the size and scope of the proposed reef habitat, the structures will be placed over a period of several years, which provides opportunity to make adjustments based on lessons learned. The first placements are proposed in areas determined (Lipcius et al. 2008) to be highly likely to recruit sufficient sessile invertebrates, particularly oysters, to meet secondary production metrics. Also, several different types of reef structures will be deployed, so we can collect data on which structures are best in the Lynnhaven and for different uses, such as shallow nearshore vs. deep water subtidal deployment. Fish, which are highly motile, will be attracted the reefs wherever they are placed, since the sites selected all have appropriate salinity regimes for the various reef-utilizing species.

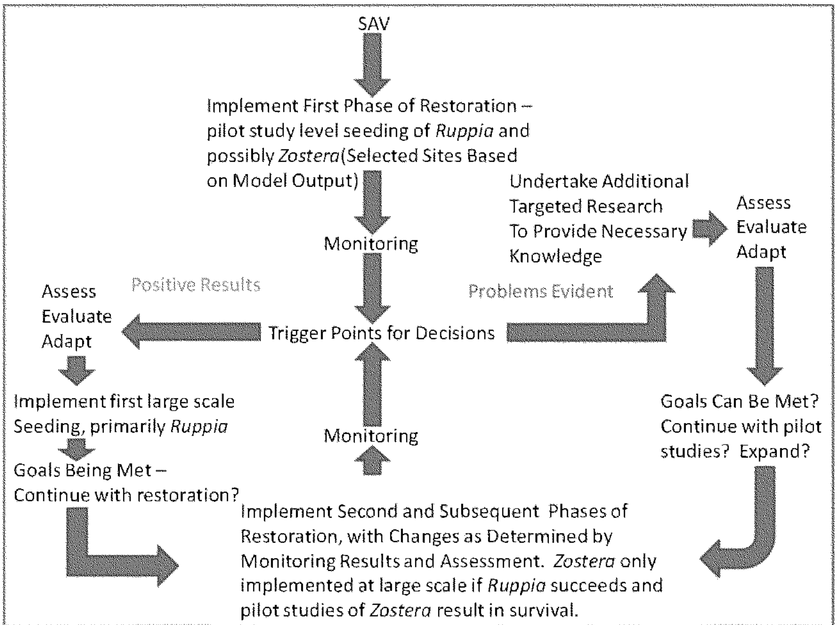
Based on the initial results, future reef placement will be considered and possibly modified in order to improve performance. Modifications could also include changing the shape, conformation and/or placement grid of the structures to improve performance as well as selecting alternative areas for placement. An additional measure would be to modify the design of the individual reef structures, as their shape can affect the surface area that is fully exposed to predation as well as sheltered internal areas not so exposed. Conformation changes could include changes in the concrete and stone mix to be more attractive to sessile larva for settlement or to enhance surface rugosity to provide for increased shelter for small post-settlement reef organisms. Extant reef structure, if failing to meet metrics, will also be considered for AM actions, of which there are primarily two: cleaning or moving to another location. However, before any AM action on placed structures is considered, all possible reasons for not meeting expected metrics should be considered as it is likely better to simply wait and give the reef habitat more time to produce expected benefits. Storms during times of recruitment, Bay-wide poor water quality (anoxia, high temperatures due to regional heat wave) can significantly lower recruitment and natural impacts to the reefs need to be considered prior to AM action other than waiting. Although there are other possible options available for improving the productivity of placed reef structures, two are described presently. If the reef structures become covered with sediment, divers could be hired to clean off the reef structures, or possibly a small dredge could be run in reverse, blowing off the sediments from the reef structures. This is not an expected maintenance event, and will only be done in the event a major storm results causes high enough sedimentation on the reefs that it overcomes the oysters' and other filter feeders' abilities to clear the reefs of the sediment. This clearance can take several months, so this action will not be triggered until at least a season of biological activity occurs post-storm on the reefs. A storm during the winter that deposits significant sediment on the reefs will not be removed by biological activity due to low metabolic rates of sessile reef organisms during the winter, though water currents may sweep the reefs clean despite the lack of biological activity prior to the spring warm up and resumption of activity by the reef organisms. While some small amount of settlement is anticipated, a few inches, if the concrete structures sink into bottom substrate more than that, the reef structures could be pulled up and placed in a more stable area. This could even be achieved before the construction is complete as the construction time frame is a long enough period for any settlement to occur. Construction will be sequenced for the larger, heavier reef structures to be placed first and the lighter, smaller reef structures done last. This would allow for monitoring to be done after placement to address any settlement issues for the larger reef structures. The smaller reef structures are less likely to settle into the substrate as they are much lighter but lessons learned in the placement of the larger reefs structures would be utilized in the placement of the smaller variety. Additionally, a local NGO, Lynnhaven River NOW has placed reef balls and other structures, including interlocking concrete "oyster castles" of the small variety that would be used in Lynnhaven Bay, in both nearshore and deeper water applications. The monitoring of these done by the NGO and the lessons learned they can provide would also serve to inform on what could be expected when placing the smaller reef structures and perhaps modify their placement area and design in order to achieve additional benefits, such as shoreline stabilization and increasing estuarine marsh acreage due to sediment accumulation and stabilization in the lee of the structures. Adaptive management measures will also be considered after major storm events, but only after ROV monitoring is done to assess the reefs and sufficient time passes to give the living organisms on the reefs to clean them off. Monitoring would be conducted after a storm event to determine if storm generated currents shifted or scowered underneath reef structures to cause shifting or settlement. Monitoring would generally be done in the latter part of the fiscal year but would be adjusted to react to a major storm event, which would typically be a hurricane. The results of the monitoring would determine the appropriate adaptive management measure as well as to inform if monitoring would be necessary after future storm events.

Associated Costs

Hiring divers to clean off the reef structures would add approximately 2 percent to construction costs. Removing the reef structures from the sediment and possibly moving them to a more stable location would add approximately 10 percent to construction costs. Modifying the placement and/or designs of the reef structures as the project is phased in to take advantage of lessons learned from prior deployments should not add significantly to the construction costs of the project. $1,534,098 has been budgeted for adaptive management of EFH.

SUBMERGED AQUATIC VEGETATION

SAV may require more extensive adaptive management than the other options of the selected plan. It is expected that once seeded, beds should persist and hopefully provide seed that will establish new beds in other locations in the river. Due to the technical challenges of SAV restoration, pilot studies will constitute the initial effort. Pilot level study sites of less than an acre will be seeded at several of the locations recommended in the proposed plan. These sites will, at first, be mostly to entirely *Ruppia,* due to its greater tolerance for higher water temperature and general hardiness compared to *Zostera*. Variations in current energy will be one of the variables assessed, as SAV may perform better in areas with lower than average (for the Lynnhaven River) wave and current energy in the river, though the opposite may also be true. The objective of the pilot studies is to assess the ability of SAV to survive and grow in the Lynnhaven without making the large commitment to seed wholesale the proposed project areas and make final adjustments to the large-scale seeding using the results of the pilot studies. These results in additional decision points in the SAV AM plan, compared to the fish reef AM plan. The basic SAV AM plan is explained graphically below:



The additional steps are due to many reasons, the first of which are the more variable track record of SAV restoration in Chesapeake Bay, SAV populations have been in general decline in the Bay, no large-scale attempt to restore it has been made in the Bay in some time. Additionally, prior attempts were using the older methods of transplantation of mature plants, not the modern methodology of direct seeding as proposed in the present study and focused almost exclusively on eelgrass, *Zostera,* not the hardier widgeongrass, *Ruppia,* that the present study recommends. The first decision point occurs after the pilot study seeding. If the SAV grows and survives, it is likely that the program will be expanded the following year. If not, results will be evaluated and a cause determined if possible. Additional pilot-study plantings and research may be done to gather more data on local conditions, problems and opportunities for restoring SAV in the Lynnhaven River. For the pilot study(s), growth and survival of the SAV is the objective. Pilot study sites may also have predator exclusion (cow-nose ray) netting installed in order to prevent the rays, whose foraging habits can be disruptive to SAV, off the test plots. No specific density (shoots/m^2) is required for the pilot study(s), though there are density objectives for the large-scale seeding as the density of SAV determines secondary production as well as the probability of long-term persistence. Further pilot studies and adjustments to seeding locations may be needed in the next phase, depending on what the cause was for the seeding failure. Reasons a pilot study level seeding may not work as well as desired include, but are not limited to variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), excessive or insufficient water currents, or potentially a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. These can be fairly easy to determine and treat. Reasons a seeding may not work as well as desired include variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), or a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. Other reasons could be a local or regional decline in water quality, which would be more difficult to address.

Adaptive management measures would typically involve over-seeding beds to improve performance in the event that seeding does not take at desired densities in any selected area, abandoning a faltering site and moving a site or sites to regions of better current flow, anti-predator exclusion from the beds to discourage destructive foraging, better signage to discourage boat propeller damage or relocation of sites to areas of lower boat use. Passive actions are also possible, mainly waiting to see the results of a seeding and while gathering additional monitoring data to better influence decisions. The expected secondary production values for a fully successful SAV restoration attempt are displayed in the following table.

SAV Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	77.6
1	155.2
2	310.4
3	620.8
4	1008.8
5	1552.0

*year of initial seeding after pilot studies are completed with positive results

Monitoring

The SAV beds will need monitoring to assure long-term persistence and to measure any expansion or changes in density of the SAV over time. The monitoring program for SAV should include an annual survey to assess the extent, density, and productivity of the beds for five-ten years post construction. A water quality monitoring program is already in place and data collected from it will also be consulted, as SAV persistence is dependent on good water quality. In the Lynnhaven, the minimums for the more fragile SAV species, eelgrass, are 15% light penetration at 0.5 m depth, < 15 ug/l ChlA, < 0.15 DIN (mg/l) and <0.02 DIP (mg/l). Widgeongrass is considerably more tolerant of lesser water quality and should be easier to establish. It is important to note that these parameters are, on average, met in the areas of the Lynnhaven selected for restoration. SAV beds mature quickly, as do their associated benthic communities, and five years should be sufficient for the beds to mature and the benefits to match that of SAV beds located in small bays along Virginia's lower Eastern Shore. However, since the strategy focuses (especially at first) on a somewhat less persistent species, *Ruppia,* newly established SAV beds will need to be monitored for stability longer than the time needed to initially establish them, which may take only a year or two. After the first five year period, if the SAV beds are persistent, monitoring could be relegated to the annual monitoring program conducted by Virginia Institute of Marine Science (VIMS) that encompasses the entire Chesapeake Bay and includes the Lynnhaven River system. If not, it is recommended that the more extensive monitoring continue to be done for another five years for 10 years total monitoring. For the initial five year period, however, it is important to establish a more comprehensive monitoring program. Such a program would involve random samples within restored SAV beds, to determine both the health of the SAV as well as secondary production within the beds. Water quality data is already being collected by other agencies, though data on water currents may need to be collected in addition to this and such work would likely be funded under the present study's proposed plan.

For SAV, the cost of monitoring is also estimated to be $40,000 per year for the first five years of the project, which may be continued if necessary for another five years. After this period, no additional money has been allocated for SAV monitoring because it is anticipated that the project areas will be incorporated into the annual SAV monitoring program conducted by VIMS. Adaptive management may dictate otherwise but it is hopeful that this will not be needed.

Adaptive Management

Seeding new areas that appear to be suitable but are not colonized by SAV could be implemented despite the success of the proposed beds in the selected plan. There may be subtleties in local hydrodynamics that prevent the propagules of successful beds from colonizing isolated regions of the river system, especially one as complex as the Lynnhaven.

Reasons a seeding may not work as well as desired are variance in seed viability, storm events immediately after seeding before seeds become anchored in the sediments, damage to new SAV beds by cow-nose rays or boat propellers (which can be extensive), or potentially a strong storm event such as a hurricane or Nor'Easter that could damage a newly established SAV bed. Summer heat waves can be challenging for SAV, especially *Zostera.* These can be fairly easy to determine and treat, except for weather-related impacts. Other reasons difficult to overcome via management decisions altering the construction plan could be a local or regional decline in water quality. In the cases involving physical damage to the beds, the cost to re-seed would approach 10% of the initial seeding costs to help low- shoot density SAV beds increase to the desired level faster, as the risk is that low density beds will continue to decline without intervention. Low density beds are those that have 10% or less of the area measured with SAV vegetation present. The corps could also consider seeding in areas near established beds to encourage more rapid expansion. This option would cost less, up to approximately 5% of initial seeding costs. This measure would be employed if bed expansion does not occur, but the established bed persists at above low shoot density (if it does not, the entire bed will have additional SAV seeds applied within it).

Another measure could be to seed new areas that appear to be suitable but are not colonized by SAV despite the success of the proposed beds in the selected plan. There may be subtleties in local hydrodynamics that prevent propagules from successful beds from colonizing isolated regions of the river system, especially one as complex as the Lynnhaven. Monitoring results that assess current speeds within areas that develop SAV could be used to refine these choices. Such an option could cost 10% or more of the initial seeding costs, depending on the number of areas to be seeded. These sites will be identified post-initial construction, as these areas will not be apparent until SAV beds are established and expansion of the beds into new areas is documented. This will take at least 2 years after initial seeding to observe. Temperature data will be consulted, as the Lynnhaven River is near the edge of eelgrass' (*Zostera marina*) range and if the restored eelgrass dies back and the problem can be identified as temperature stress, the re-seeding may either only be with the more temperature tolerant widgeongrass (*Ruppia maritima*) or seed with more temperature tolerant eelgrass, if such can be found. There is evidence that *Zostera marina* displays genetic differences regarding temperature tolerance (Ehlers et al 2008) but for local use no such strains have been identified at this time. Additional adaptive management actions could include signage requiring "no wake" zones over restored SAV beds, to reduce prop damage within the bed or possibly marking the SAV beds "off limits" to boat traffic, at least those located in shallow (< 3ft MLW) waters. This will be considered if prop damage to established SAV beds is observed. Such options would help existing, established beds maintain their integrity over time, as there is extensive boat traffic in the Lynnhaven. If the damage is due to cow-nose ray foraging, the only solutions are to protect the beds physically with nets or fencing, lower the numbers of rays (via a fishery, for example) attempt to restore SAV further upriver in lower salinity waters where cow-nose rays do not frequent (this option would likely preclude use of eelgrass and rely on widgeongrass only, as it is more tolerant of low salinity) and/or re-seed the beds. If the SAV declines or fails to establish and the cause is determined to be poor water quality, water quality monitoring data that is collected by the City of Virginia Beach will be reviewed for specific water quality issues.. Eutrophication can occur in the event of a drought followed by above average rain events, and this can cause spikes in ChlA, DIN and DIP above levels tolerable by SAV. These levels should abate with time and the SAV, if still present, can recover. If not, and water quality improves it could be re-seeded. If the decline is caused by other events, such as a decrease in overall Bay water quality, seeding with eelgrass may not be implemented and only widgeongrass, the more environmentally tolerant species, may be used until water quality improves sufficiently to warrant eelgrass establishment. If enough SAV can be established, these parameters are less likely to be exceeded as SAV itself utilizes the same nutrients that can cause phytoplankton blooms due to eutrophication.

In any area that is difficult to access by boat or if currents are strong or irregular, buoy deployed seeding would be utilized. This technique helps insure that the seeds, when dispersed, stay in an area around the buoy by releasing them slowly over time. This process lets the dispersal take place across a variety of conditions and would mitigate the risk of losing broadcast seeds due to storm events or currents shortly after the seeds were cast to the water (Pickerell, et al. 2006).

Decision points are after every year's monitoring. If results are at least 50% of expected secondary production values, the project will likely require no AM action other than continuing to monitor the site(s) to see how they progress. If the original effort to establish SAV is not successful, the project area will be reseeded unless it is determined that an underlying cause that cannot be addressed (such as unfavorable current velocity that could not be altered by additional reef placement or what appears to be a long-term regional decline in water quality (Bay-wide), in which case a particular site(s) may be abandoned. Re-seeding should also take place if the SAV beds are only scarcely vegetated (density ≤ 10%), as additional seeding will help low-density SAV beds increase to the desired level faster and reduce the risk that the low density beds will continue to decline without intervention. If secondary production values are not meeting at least 50% of the objective, a decision point is reached. If this failure is due to disruption of the SAV by weather events, unless total loss occurs the likely decision will be to wait to see if enough seed and underground rhizomes remain to recover the bed, as SAV is resilient in the face of this type of event and can often recover, once established, on its own due to available seed and rhizomes, which often remain buried in the sediments while above ground biomass is swept away by the storm event. If the failure is determined to be from a water quality cause, such as a heat wave, waiting is the likely recommendation unless total loss of both above and below sediment SAV has occurred, in which case re-seeding is recommended. If the cause is physical damage (boat props and/or cow-nose rays) measures can be taken to discourage this, including signage and physical barriers.

Associated Costs

The cost to re-seed would approach 10 percent of the initial seeding costs, while seeding in areas near the established beds would cost less, up to approximately 5 percent of initial seeding costs. Seeding new areas, outside of the project site, could cost up to 10 percent of the initial seeding costs, depending on the number of areas to be seeded. "No wake" signage would have minimal associated costs, perhaps 1-2 percent of initial seeding costs. $190,520 is the estimated cost of adaptive management for SAV.

BAY SCALLOP RESTORATION

Scallop restoration will only be attempted if core bed acreage (the minimum SAV option as described in the attached report) is at least present, as scallops are highly (though not exclusively) dependent on SAV as shelter for their juvenile stage. Scallop restoration will only proceed if several beds of SAV can be restored and show persistence by surviving for several years. The scallop is a short-lived mollusk and in the Lynnhaven will essentially function as an annual crop, though some can survive for two years. Once established, and assuming the SAV persists, the scallops should persist along with the SAV. However, scallops are vulnerable to predation and possibly environmental disruptions, such as major storm events. The restoration efforts will, similar to SAV, begin with pilot-study level efforts and commence from there. The objectives of the pilot study efforts is to determine if scallops reproduce in the Lynnhaven as well as gather data on the most efficient means to restore a breeding population. It is expected that these efforts will be less and shorter in duration than those for SAV, as the Corps has already funded a large-scale pilot study on scallops in the Lynnhaven River (Hernandez-Cordero et al. 2012). The results of this study indicated scallops can survive and grow in the Lynnhaven River on a variety of habitats, including oyster reefs, SAV, and macro-algae. The pilot study will focus on how best to implement wide-scale restoration, as there are a number of techniques available, including keeping spawning adults in cages so they spawn at high efficiency, release of juveniles and/or adults into SAV beds, to potentially releases late-stage larvae into SAV beds. It is expected that a combination of efforts, likely focusing on caged adults with some stocking of juveniles, is the likely restoration regime but the pilot study will assist in fully developing this plan. Expected productivity for scallops is described in the following table:

Scallop Secondary Production Over Time

Year	Secondary Production (kg/acre/year)
0*	11.5
1	22.9
2	45.8
3	91.6
4	148.9
5	229

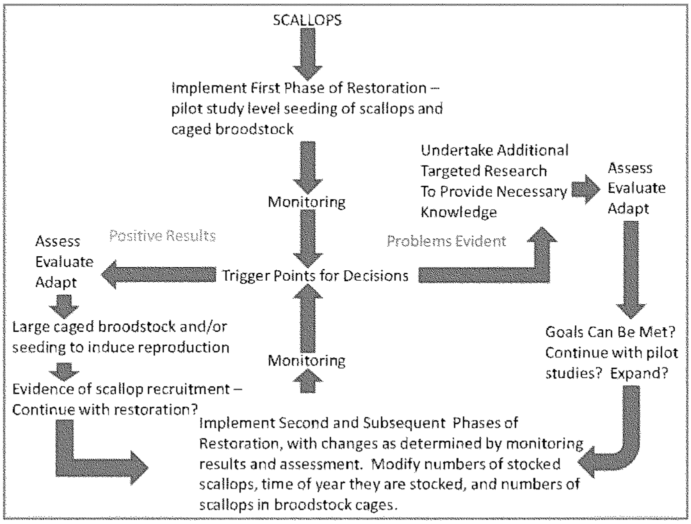
Monitoring

Scallop populations will need to be assessed in habitat they can colonize, which consists of SAV beds, gracilaria (macroalgae) beds, and oyster reef habitat. Monitoring can follow standard protocols for assessing scallops, which include counting them along transects or assessing their numbers in discrete sampled areas. Recruitment outside the restoration areas can be measured by "spat bags," which are loose bags of dense nylon nettings that scallop juveniles will set upon and grow. If the scallops recruit successfully, they should establish a self-sustaining population quickly, within five years of initial stocking. Monitoring should be more extensive during the first five-ten years, as this is the critical time for population establishment and deciding whether or not to implement various measures within the adaptive management plan. Monitoring costs for an annual scallop survey of juveniles and adults and an associated spat bag survey to assess abundance, dispersal, and recruitment, should be expected to cost approximately $40,000 to $50,000 annually for the five year period. After this, a smaller scale survey could be implemented to ensure the scallop population remains viable, and this smaller survey should cost no more than $15,000 per year. If the goals are not reached, however, the more extensive monitoring should remain in place for another five years while the adaptive management plan is implemented.

For all monitoring, if extensive adaptive management measures are needed, this would essentially re-set the "clock" on the monitoring plans. That is, if there was an extensive SAV die back during year 3 and complete re-seeding was needed, five years of extensive monitoring would be required, starting the year of the re-seeding.

Adaptive Management

Scallop restoration will only be attempted if core bed acreage (the minimum SAV option) is at least present, as scallops are highly (though not exclusively) dependent on SAV as shelter for their juvenile stage. Scallop restoration will only proceed if several beds of SAV can be restored and commence at least 1 year after successful SAV bed establishment. Once established, and assuming the SAV persists, the scallops should persist along with the SAV. They will also colonize other habitat, such as macroalgal beds (*Gracilaria* sp.), and oyster reefs in significant numbers. However, scallops are vulnerable to predation, and possibly environmental disruptions such as major storm events. The basic scallop AM decision tree is as follows:



There are several adaptive management measures that could be considered in scallop management, as follows. As with prior portions of the plan, the objective is to reach at least 50% of the secondary production goal. For scallops, evidence of successful reproduction is also a requirement and the establishment of a self-sustaining population is a primary objective, along with the secondary production goal.

In order to reduce risk from predation, the corps could consider fencing off limited areas (perhaps 10X10 square meter plots) within SAV beds determined to be the main areas supplying scallop recruits to other areas. The predator that can cause the most extensive damage to a scallop population, the cow-nose ray, would be kept out by such a measure. The corps could then preferentially stock within these predator exclusion areas, in order to better insure initial survival. The corps could also stock at very high densities within these fenced areas, in order to improve reproduction of the scallops to enhance recruitment. This is a relatively inexpensive measure, and would be up to 5% of the initial seeding costs. This predator exclusion could also be done if re-seeding is required, and done more extensively. In this event, up to 10% of initial costs would be necessary; to cover the addition of hatchery produced juvenile scallops within the fenced-off areas. Other adaptive management actions could include collecting juvenile scallops on volunteer or contractor deployed spat bags placed under docks or within or near existing SAV beds and then stocking these juveniles more heavily within established SAV beds to increase the population density of the scallops in order to improve both the environmental benefits they provide as well as their reproductive efficiency. Due to the extensive environmental group membership in the local area, it is likely that such spat collecting done by volunteers could be quite extensive and contractor deployed spat collectors used less extensively as a result. Costs for spat collecting would likely be relatively small, perhaps up to 5% of initial seeding costs. This measure will likely be considered if recruitment does not seem sufficient or if the need to collect additional data on recruitment is needed beyond the scope of the proposed monitoring plan.

A further adaptive management measure would be to deploy scallops in cages at very high densities to maximize reproduction and subsequent recruitment. This will be considered both in the initial stocking as well as if recruitment does not appear to be adequate to establish a self-sustaining population and additionally seeding proves necessary. Such techniques are showing success on the lower Eastern Shore of Virginia in re-establishing scallops in restored SAV beds there.

Predator control via commercial fishing of the rays could also be considered, and is currently under discussion by the state fishery management agency (Virginia Marine Resources Commission (VMRC)). This is due to the noted increase in cow-nose rays in recent years, which also cause extensive mortality to clam beds and commercial oyster lease holds. Predator control would consist primarily of developing a commercial fishery for cow-nose rays, which, while not a USACE action, the USACE will provide input to VMRC.

After each year's monitoring, the scallop population will be assessed. Three basic questions will trigger decision points, and these are: Is there evidence of successful reproduction? Are numbers of adults increasing? Are secondary production goals being met? Failure to meet any of these three will trigger the AM plan.

In the event of unsuccessful reproduction, unless a weather event, such as a hurricane, can be identified as the cause, the likely cause is too few spawning adults. In either event, the appropriate response is to augment the spawning population the following year in order to avoid a population crash. This can be done using any of several techniques described above, particularly stocking of juveniles and/or adults directly into the SAV beds or placement of spawning adults in cages near SAV beds which will release larvae into them.

If the population of adults appears to be reproducing, but decreasing in numbers, this may trigger an AM response. SAV beds should first be assessed for their fitness, as decreasing shoot density exposes the scallops to increased rates of predation. Evidence of cow-nose ray feeding within SAV beds should also be assessed. Cow-nose rays disrupt the bottom when they feed, creating a hole approximately 1foot in diameter and 6" deep. Large numbers of these holes in SAV beds would identify the ray as the primary culprit in decreasing numbers of adult scallops despite successful reproduction. Anti-predator exclusion netting is the cheapest measure to discourage the rays, though if a fishery for them could be developed, this would also ease their predation pressure on the scallops as well as other benthic life in the Chesapeake Bay though this action is outside the AM plan. Other causes could be inadequate recruitment. This could be caused by poor water quality during the larval phase, particularly large inputs of freshwater which reduce larval survival and growth, as well as flush them out of the river into the Bay. The appropriate AM response in this case will be to augment the spawning stock by means already described.

Failure to meet secondary production goals will also trigger the AM plan. If the scallops appear to be reproducing and adults are surviving in adequate numbers to produce a self-sustaining population (or one that seems to be increasing) no action should be taken and a "wait and see" approach is recommended. Scallops may develop a stable population at a lower than expected level in the SAV beds, considering that they can survive on other substrate that is present in large amounts (macroalgal beds, oyster reefs) in the Lynnhaven River. These scallops on alternative substrates could provide significant secondary production such that goals are actually exceeded, though not exclusively via the scallops in the SAV beds habitat. Routine monitoring of the oyster reefs built under the 704(b) program would provide some data on scallops utilizing this habitat type. Additionally, this goal may need to be reassessed if this situation occurs, as the primary objective is to establish a self-sustaining population of scallops. The secondary production numbers were developed using more southern populations of scallops, and the numbers for Lynnhaven River's distinct scallop sub-population may be somewhat different.

Associated Costs

Fencing off areas within SAV beds is a relatively inexpensive measure, and would be up to 5 percent of the initial seeding costs. If predator exclusion is done in conjunction with SAV re-seeding, then the associated costs would be as high as 10 percent of initial costs to cover the addition of hatchery produced juvenile scallops within the fenced-off areas, while the costs associated with spat collection would likely be relatively small, perhaps 5 percent of initial seeding costs. 10 percent of the constructions costs, or $316,001, has been set aside for the adaptive management of bay scallops.

WETLANDS RESTORATION AND DIVERSIFICATION

The monitoring and adaptive management (AM) plans for the two different wetland treatments will vary slightly due to the overall project objectives.

Monitoring

The four wetland sites will be monitored twice annually. The monitoring efforts will be completed by either a USACE employee with a background in wetland function and plant identification or a contractor with a similar background. The results of monitoring efforts, whether they are completed by USACE staff or a qualified contractor, will be recorded and presented to the USACE within 30 days after monitoring has been completed to allow for the planning of adaptive management measures. The USACE, Norfolk District will maintain the monitoring data.

Restoration Sites

The project objectives for the Princess Anne (PA) and the Great Neck North (GNN) sites include the restoration of the indigenous salt marsh community and reduction of the invasive plant species, *Phragmites australis*, present on-site. The key parameters that will be monitored at these sites during the adaptive management phase will include:

1. The presence of *Phragmites australis* in the restoration site,

2. Success of native plantings,
3. Integrity of habitat features (streams, pools, islands, etc.).

These three parameters are directly related to the achievement of an indigenous community and eradication of the exotic species.

The presence of *P. australis* must be monitored regularly for two reasons. First, the eradication of this invasive is rarely accomplished in one season. Instead, an infestation of *P. australis* is eliminated in small increments over a series of years. Second, if any *P. australis* remains at a site, the plant will continue to spread and replace the native plants. The monitoring of *P. australis* will be considered successful and complete once no is found on site.

Monitoring the native plantings will be necessary to fulfill contractual obligations and to ensure the success of the project. The planting contract will stipulate that the contractor must replace plants if a certain percentage (15% typically) fail during the first year. Later, plant success was be monitored to ensure that the design of the project was correct. For example, native marsh plants will succeed in a narrow elevation range. Even if the design is correct, there are many hazards that could interfere with the success of the native plantings. The native plantings will be considered successful if 85% of the planted areas are covered with native marsh grasses.

The final element of the monitoring plan will be assessing the constructed habitat features. Each feature will be observed to determine if it is structurally sound and functioning as intended. For example, tidal creeks and streams will be observed to make sure they have not become occluded and no longer allow the full tidal inundation. The upland mounts will be monitored to see if they remain at an elevation that supports upland plants and have those upland plants are not overrun by *P. australis*. This element of the project will be considered successful if the integrity of each habitat remained sound for three years and 85% of the upland island areas are covered with native plants.

Diversification Sites

The "restoration" goals proposed for the Mill Dam Creek (MDC) and Great Neck South (GNS) sites do not include the establishment of a *Spartina spp.* dominated salt marsh. Instead, the ecological function of the two sites will be improved through habitat "diversification," specifically habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous *P. australis* stands. The key parameters during the AM phase to be measured at the sites where diversification has been implemented will include:

1. The presence of *Phragmites australis* in the constructed features that would impede the growth of native shrub plantings and would fill in tidal streams and pool,
2. Success of native plantings,
3. Integrity of features (streams, pools, islands, etc.).
4. Estimation of Secondary Production

The four parameters to be measured during monitoring ensure that the habitat features which have been created during the construction phase of the project remain viable. The monitoring activities and success criteria are described in the previous paragraphs. Annual costs of $7,600 over the first 10 years of the project, and $3,800 thereafter, are estimated to be the monitoring cost associated with the wetland sites. The maximum number of years (10) of monitoring is recommended for the wetland sites because the elimination of *phragmites* has been shown to be an ongoing process that requires many years of monitoring and removal efforts to be successful. Each cost estimate accounts for monitoring efforts required for the maximum acreage of each measure. For alternative plans with fewer sites, and thus less acreage, the monitoring amount was reduced accordingly.

Adaptive Management

Using the data collected through the monitoring program, USACE staff will be responsible for determining if AM is required at the wetland sites. The USACE will also select the AM measures, though other experts maybe consulted. Contractors with the appropriate background and expertise may be hired to implement the AM efforts; however the USACE will oversee the completion of adaptive management activities. AM measures are primarily herbicide application and replanting of native vegetation. Species of native vegetation may be altered, pending monitoring results, as different species than those initially selected may survive better considering the hydrology of the sites several years post-grading as well as the need to compete with other plants, including nearby *Phragmites*. Depending on the site, the replanting may vary the species in order to improve subsequent survival, as initial choices may not have been ideal, based on how the site performs over time.

A number of different strategies have been used to manage *Phragmites*. These include burning, mowing, manual removal of plant material and the application of herbicides. Since *Phragmites* management has been a recurring problem along the Eastern sea board for many years, other management plans have included common elements. So although any of previously listed actions will be available for AM of the wetland sites, it is highly probable that certain actions will be part of the plan. These actions, the application of herbicides, replanting native salt marsh vegetation, or repairing marsh features (pools, stream, or islands), are discussed in further detail in this report. However, this does not preclude the use of any effective strategy that will allow the project to fulfill the environmental objectives.

Restoration Sites

If *P. australis* is found within the restoration site, herbicide, approved for aquatic use, will be applied to the invasive species. The method of application (whether ground or aerial) will be determined by the location and density of invasive plants. The application of herbicide will occur when *P. australis* is still active, but when the native marsh plants have gone dormant, in order to reduce unintentional damage to the plantings and native plants. This period typically occurs during the last two weeks in September; however, this timing may be altered during drier years. The timing of herbicide application will be altered if annual precipitation levels are below normal levels.

If more than 15 percent of native plantings have failed, the dead vegetation will be replaced with plants for the same species. If it is concluded that replacing the original planting will ultimately be unsuccessful, then another solution (e.g. planting another species) may be implemented.

The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water moves freely through the channel. If the stream is occluded, the feature will be repaired to allow flow.

The shallow pools should remain open and free from vegetation. If the areas are beginning to be colonized by *P. australis*, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be checked for the success of native shrub plantings and re-colonization by *P. australis*. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings would be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands. If *P. australis* has re-colonized the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the plant from the habitat features.

Diversification Sites

The habitat features created at the GNS and MDC sites will be observed for colonization of *P. australis*. If *P. australis* is found on the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the common reed from the habitat features. The shallow pools and tidal creeks should remain open and free from vegetation. If the areas are recolonized by *P. australis*, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be monitored for the success of native shrub plantings. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings will be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands.

The integrity of the habitat features will also be evaluated. The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water flow moves freely through the channel. If streams are blocked, the feature will be repaired to allow flow. The integrity of the open pools and islands will also be observed to ensure that they are fulfilling their original purpose (i.e. increase habitat diversity at the site). If it is determined that the features are not improving the function of the site, they will be modified in order to meet project goals.

Secondary production will also be assessed. Expected values are as follows:

Wetland Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	12.1
1	24.2
2	48.4
3	96.8
4	157.3
5	242

These values are closely tied to the success of the plantings, and as wetlands restoration methods are much more well-established than other portions of the plan, it is expected that if the plantings survive, these values will be achieved. The AM plan is triggered in the event of excessive casualties of the plantings, which directly relate to the values provided in the above table.

Associated Costs

It is foreseen the certain adaptive management actions, such as the application of herbicide and the replacement of native plantings, will occur annually. Larger actions, such as the restoration the integrity of habitat features, requiring the physical alteration of the site will be planned every 5 years. The monitoring and adaptive management program will take place over a 10-year period.

The adaptive management costs associated with the wetland sites will be as follows:

Princess Anne - $53,160

Great Neck North - $11,757

Great Neck South - $13,273

Mill Dam Creek - $1,765

Adaptive Management Determination and Closeout

The monitoring program and pre and post construction surveys would be utilized to determine if any adaptive management is needed and what kind to proceed with. This determination would be made by the project delivery team made up of personnel from the Corps of Engineers and the City of Virginia Beach. Costs for the AM decision process have been included in monitoring cost estimates. AM measures will be implemented at any time over the first 10 years post construction by the USACE. After that, if AM is required, it will be the responsibility of the local sponsor, the city of Virginia Beach.

COASTAL ZONE MANAGEMENT SUMMARY CONSISTENCY DETERMINATION DESIGNATIONS

COASTAL ZONE MANAGEMENT SUMMARY CONSISTENCY DETERMINATION DESIGNATIONS

LYNNHAVEN RIVER BASIN
ENVIRONMENTAL RESTORATION PROJECT
VIRGINIA BEACH, VIRGINIA
SUMMARY CONSISTENCY DETERMINATION

CONSISTENCY REVIEW: Information presented in this summary consistency determination can be found in the accompanying Environmental Assessment, dated September, 2010.

PROJECT DESCRIPTION: This project will involve the restoration and protection of the water resources of the Lynnhaven River Basin. The project includes four elements. 94 acres in the main stem and Broad Bay will be seeded to produce submerged aquatic vegetation habitat. When SAV becomes established, bay scallops will be grown on site to build a self-sustaining population. Essential fish habitat will be constructed in Bread Bay and Lynnhaven Bay through the placement of concrete reefs. And, finally, restoration efforts will occur at four wetland sites.

PROPERTY CLASSIFICATION: The construction of reef habitat and restoration of submerged aquatic vegetation (SAV) will occur in areas that are state owned river bottom. The state has granted 10-year oyster/scallop ground leases in portions of these areas which will not be compatible with the project. As part of the project, oyster/scallop ground releases covering the remaining term of the existing leases will have to be acquired. The bay scallop restoration will be done on the SAV sites one year after they are constructed. The real estate interest acquired for the SAV restoration can be used for this portion of the project, and no additional interest will be required for this construction. The wetland sites are upland and will require a wetland easement for construction and maintenance.

IMPACTS TO RESOURCES/USES OF THE COASTAL ZONE: See table.

DETERMINATION: Based upon evaluation of impacts analyzed in the Environmental Assessment, the Norfolk District Corps of Engineers has determined that the proposed project will be undertaken in a manner consistent to the maximum extent practicable with the Commonwealth of Virginia's Coastal Zone Management Program.

FEDERAL CONSISTENCY DETERMINATION
COASTAL ZONE MANAGEMENT ACT OF 1972, AS AMENDED
VIRGINIA COASTAL RESOURCES MANAGEMENT PROGRAM
LYNNHAVEN RIVER BASIN, VIRGINIA BEACH, VIRGINIA

Enforceable Program	Approval/Permit Obtained
1. Fisheries Management	Finfish and Shellfish: Short-term negative impacts described in the EA. Long term goals of the project will be beneficial to finfish and shellfish TBT Regulatory Program: No TBT possession, sale, or use related to project (N/A).
2. Subaqueous Lands Management	Encroachment upon state-owned bottom – will obtain VMRC Permit. Activity involves discharge of fill into waters of the United States, specifically the placement of concrete reef balls and restoration of wetlands (addition of clean fill and alteration of marsh substrate). – State Water Quality Certification will be obtained from DEQ.
3. Wetlands Management	This project will result in impacts to tidal marsh. Some short-term, adverse impacts have been identified in the EA. However, long-term goals of the project include removal of an invasive plant species and/or increased habitat diversity. A Virginia Water Protection Permit will be obtained from DEQ.
4. Dunes Management	No destruction or alteration of primary dunes will occur as part of this project (N/A).
5. Non-point Source Pollution Control	Implementation of BMP's during construction.
6. Point Source Pollution Control	No VPDES impact. State Water Quality Certification under Section 401 of the Clean Water Act will be obtained. Involves discharges of fill material into waters of the United States.
7. Shoreline Sanitation	No activities related to installation of septic tanks (N/A).
8. Air Pollution Control	Although there will be minor air pollution increases from construction equipment, these increases will be short-term and below *de minimus levels*. Clean Air Act conformity determination completed in EA.

ECOLOGICAL BENEFITS

LYNNHAVEN ECOSYSTEM RESTORATION, BENEFITS MODEL INFORMATION

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LYNNHAVEN ECOSYSTEM RESTORATION, BENEFITS MODEL INFORMATION

ECOLOGICAL BENEFITS

For the proposed study, a wide variety of options were considered, including SAV (submerged aquatic vegetation) restoration, wetland restoration, fish reefs, scallop restoration, environmental dredging, and dam removal to restore freshwater impoundments to their former estuarine, tidal nature. Environmental dredging and dam removal were eliminated prior to forming alternative plans and will not be discussed further, nor were they considered in the model this document describes.

The options that were considered during the plan formulation include wetlands restoration, SAV restoration, fish reefs, and scallop restoration. A model was needed to relate these different options to each other, as well as to assess their environmental impacts to the Lynnhaven River system. Simple HU (habitat unit) approaches were not adequate for comparative purposes between these different habitat types. The cost to restore them also varied widely. A means to compare the ecological services they provide was needed. Several basic ecological benefits provided in various amounts by all the proposed restoration activities were considered. All of these benefits can be compared between the widely differing restoration activities in order to evaluate the benefits of each and various combinations of the proposed activities to arrive at a best buy plan.

Using functional endpoints, not structural, while different from the typical HU approach is not without precedent for the Corps or for the Chesapeake Bay. The Norfolk District's Craney Island Eastward Expansion (CIEE) project, approved in 2009, resulted in the take of open river bottom and water column above it to construct the new dredged material containment cell. The proposed mitigation plan assessed the lost secondary production because direct, in-kind mitigation was not possible because new open water habitat in the Elizabeth River system could only be created by either excavating nearshore lands or deliberately flooding them. This secondary production loss was then used to scale the replacement habitat to the level of loss of production. This approach was approved by the Corps, and the Commonwealth of Virginia. In

Maryland, the Chalk Point oil spill, which resulted in the release of 140,000 gallons of fuel oil into a tributary of the Patuxent river, impacted about 40 miles of creeks and shorelines. A significant portion of the accepted mitigation plan (2002) used lost secondary production to mitigate for lost ecological services because of the wide variety of benthic organisms and habitats that were affected by the oil. Due to the need to compare different habitat types in various configurations against each other in plan formulation, we decided to adopt this approach for the present study. Three parameters were selected, TSS (total suspended solids), Secondary Production (animal biomass produced per unit area) and BIBI (Benthic Index of Biotic Integrity, a measure of species diversity).

The proposed activities will work collectively to significantly decrease TSS, increase Secondary Production and improve the BIBI in the Lynnhaven River system. By improving these basic ecological parameters, the overall health of the Lynnhaven River is expected to improve significantly. Further, positive feedback loops exist between Secondary Production and TSS, the higher one is, the higher the other, and it is hoped that with enough restored habitat, these feedback loops will stimulate further, natural recovery in the river. These environmental benefits (TSS reduction, Secondary Production, and BIBI) are critical to the ecosystem but do not conform to a HU approach because they are functional, not structural.

The following figure is a Conceptual Model that explains how the proposed restoration can enhance the selected parameters we used in the benefits spreadsheet model found near the end of this explanatory narrative and within the report (pg. 81).

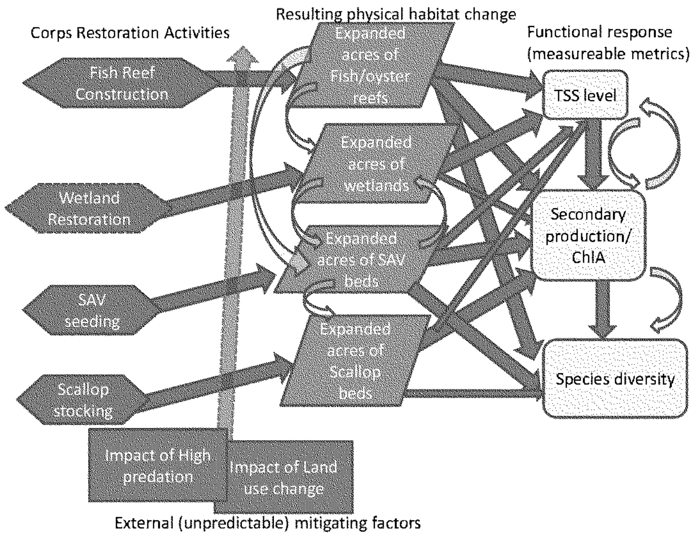

Figure 1. Conceptual Model for Environmental Benefits Model

The blue arrows represent linkages and the strength of that linkage. For example, SAV beds greatly increase secondary production but only moderately decrease TSS levels compared to other restoration options such as wetlands or reefs. Yellow arrows indicate a feedback exists, and the direction the arrow points in shows the direction of the feedback. In some cases, positive feedback loops between parameters exists. The following narrative first provides additional information on the benefit parameters selected (secondary production, TSS, and species diversity) and thier importance to the ecosystem. Following this, background information is provided on each restoration option considered, information on its potential to enhance the selected parameters, then the selection of the numbers found in the benefits spreadsheet.

Also, a means to link the project benefits to the VIMS hydrodynamic/water quality model was needed in order to assess impacts on Lynnhaven River water quality as a result of project implementation using the VIMS model. While improving water quality is not a primary objective, it is directly related to project implementation. It also serves as an indicator of the wide-scale benefits derived from project implementation. However, it is important to note that neither the VIMS model nor the model run results were used to make decisions on determining what the selected plan is.

The following sections provide background information on the selected parameters, describing their importance to the ecosystem.

SECONDARY PRODUCTION/CHLOROPHYLL A

Secondary production, that is, production of animal biomass, is often used as a standard measure of ecological health and productivity in environmental restoration work (McCay and Rowe, 2003, Peterson and Lipcius, 2003), as primary production can often be excessively enhanced by eutrophication, especially in the aquatic environment. Secondary production can be an important indicator of environmental health. It has the benefit of being a measurable, functional goal against which to judge success. Additionally, for the present study, secondary production was used as a proxy to determine how much phytoplankton was ultimately consumed to produce it. This, then, relates to the chlorophyll A parameter in the VIMS model. By reducing phytoplankton levels, local waters will become less eutrophic, which will improve water clarity and quality (Paerl et al., 2003). The secondary production will have a positive cascade of benefits for local waters, providing more animal biomass as prey to higher trophic levels, which will ultimately increase biomass of higher level predators, such as striped bass (*Morone saxitalis*), sharks, rays, drum fish (*Sciaenops ocellatus, Pogonias cromis*), cobia (*Rachycentron canadum*), blue fish (*Pomatomus saltatrix*), spotted sea trout (*Cynoscion nebulosus*), weakfish (*Cynoscion regalis*), and others. Local fisheries will also benefit. For secondary production, different environmental restoration options had their annual secondary production biomass estimated in AFDW (ash free dry weight, a measure of organic biomass produced independent of shells, water in tissues, or other materials). An annual production/biomass estimator was used to paramaterize the peak summer standing biomass to an annual production rate, which varied throughout the year with the primary driver being water temperature. The method used was adopted from work by Diaz and Schaffner (1990) for the Chesapeake Bay.

TOTAL SUSPENDED SOLIDS (TSS)

The second environmental parameter that will be improved by any of the environmental restoration options considered is TSS (total suspended solids) levels in local Lynnhaven River waters. TSS is a common measure to estimate negative human-induced impacts to aquatic ecosystems. Levels higher than pre-development levels of TSS have a number of negative impacts. TSS reduces gas exchange, increasing the chances for anoxia in tidal estuaries (Abril et al., 2009). TSS reduces water clarity, and its increase due to human impacts, primarily agriculture and urban development in the Chesapeake Bay watershed, have greatly reduced the available habitat for SAV and beneficial macroalgae due to reductions in light levels from high TSS (Tomasko et al., 2005). SAV acts to stabilize bottom sediments; its loss creates a negative feedback loop where TSS tends to increase further, making it increasingly difficult for light-dependent marine life to persist, especially rooted aquatics. Additionally, it reduces the available habitat for other photosynthetic life, such as benthic diatoms (Ulanowicz, 1994), altering the species composition, along with the associated local estuarine ecosystem and food webs. It also stresses filter feeding organisms, such as oysters, making them more susceptible to disease (Colosimo, 2007), which has been a major cause in their population collapse in recent decades. Additionally, oyster reefs can become covered with a fine layer of silt unless high densities of adult oysters are present per unit reef area, quickly rendering the reef substrate unusable for oyster larval attachment. However, functional oyster reefs or other hard substrate colonized by oysters and other filter feeders can substantially reduce TSS as they filter feed. TSS typically becomes incorporated into their waste, and often ends up deposited on the bottom, out of the water column. Fish species that require hard substrate for benthic egg laying can only use reef habitat for reproduction that is not covered with silt. Reef dependent species, such as naked gobies (*Gobiosoma bosc*), tautog (*Tautoga onitis*), and others suffer from this loss . Other filter feeders, such as clams and menhaden, are also negatively affected by high TSS levels, as they must process and eliminate the TSS during their filter feeding (Soniat et al., 1998), using energy that could be used for somatic growth or reproduction.

Another negative impact associated with high levels of TSS is increased levels of e. coli and other pathogenic bacteria. Such organisms are not commonly found free living in the water column, but instead attach to small particles of suspended sediment (Schillinger et al., 1985). Thus, lowering TSS levels may have some beneficial effects on pathogenic bacteria levels, lowering them and thereby improving water quality.

SPECIES DIVERSITY (BIBI)

Another important metric that is often used to define the health of an ecosystem is a species diversity index. Negative environmental impacts often act to reduce species diversity, as more sensitive species are often extirpated first, with increasingly less sensitive species remaining as a local ecosystem becomes more polluted, until finally only a small number of eurytopic species (tolerant of pollution and/or other adverse conditions) remain. This often results in losses of productivity as well, as in many aquatic systems pollution-tolerant species are often small nematodes and similar aquatic life, whereas larger more ecologically-important species, such as mussels and crustaceans, will not be able to tolerate such marginal environmental conditions. In these situations, species diversity declines with increasing negative environmental conditions and, conversely, improvements to the environment can be measured by increasing species diversity. Ecosystems with higher diversity are generally regarded as more mature, less polluted, and resilient, than those with low diversity (Didham et al., 2005, Suding et al., 2004). Resilience and trophic redundancy in an ecosystem are highly desirable traits. What this means is that there are typically a number of species present that could fill various ecological roles, such as filter feeding on phytoplankton in the estuarine environment. In a low-diversity ecosystem, only one or a few such species would be present, and any additional loss would tend to destabilize the ecosystem, perhaps altering its stable state to one less desirable. For example, the modern day Chesapeake Bay, has essentially lost the once-extensive oyster reefs that were formerly capable of exerting a significant effect on water quality in the Bay (Newell et al, 2007, Newell, 1988). In this case, anoxia might be the new state, as a lack of filter feeding could cause excess, unconsumed phytoplankton to die and decompose on the bottom, which could then further impact the ecosystem, until at last only the species most tolerant of poor water quality remain, if any remain. The low oxygen "dead zones" seen in the Chesapeake Bay each summer are partly due to the loss of once-extensive oyster reefs, which formerly consumed much of the spring phytoplankton crop in the Bay.

An extensive background survey of the present benthic fauna was undertaken during the scoping of the proposed project (Dauer, 2006). Additional shallow-water fish surveys were also conducted to assess nekton (Bilkovich, 2006). Both surveys showed that, in general, the Lynnhaven River is far from pristine system, habitat diversity is limited, and species diversity is considerably lower than reference, undisturbed aquatic habitat. Primary causes of this ecosystem state are loss of benthic habitat diversity, as well as the deposition of large amounts of terrestrial sediments over the sandy bottoms formerly found throughout most of the system, although extensive sandy areas are still found, particularly in portions of Broad Bay and the Lynnhaven Bay area near the river mouth.

The proposed project should act to improve the local ecosystem, and one of the expected benefits is to increase species diversity. For the present study, an index was considered, a BIBI (benthic index of biotic integrity) for the Lynnhaven River system. The BIBI for the Lynnhaven was estimated during the scoping phase of the project (Dauer, 2006). Fish diversity was also considered; however, it is not being specifically measured in the present study, though such indices have been used in other estuarine systems (Breine et al., 2010, Raposa et al., 2003, Meng et al., 2002, Deegan et al., 1997). Because the proposed project includes several components that will increase habitat for a variety of fish species, it was important to consider the impacts of the project on the local fish community. Secondary production does capture important aspects of this, but because species diversity will be increased by providing the new habitat, it is an important factor to consider in the present study.

The subsequent sections provide background information on each restoration option considered (SAV, Reefs, Scallops and Wetlands), then potential benefits numbers and restoration options. Benefits calculations then follow, along with the model spreadsheet to be certified.

SUBMERGED AQUATIC VEGETATION (SAV)

Background Information

The Lynnhaven River historically supported extensive SAV beds. Based on the salinity regime, these beds consisted of two species, eelgrass, *Zostera marina*, and widgeongrass, *Ruppia maritima*. The full extent of the original, pre-development SAV beds is not known. It is likely that they were several hundred acres in total extent. The oldest map dated from the early 1970's and shows more than 100 acres of SAV beds, mostly in Broad Bay and near the confluence of the eastern and western branches of the Lynnhaven River, including Lynnhaven Bay proper. Eelgrass in particular experienced a massive die-off in the late 1920's and early 1930's due to disease, a slime mold, *Labyrinthula zosterae*. Though never fully recovered, it did return to many areas within the Bay,where it was formerly found, by the 1950's. The SAV beds in the Lynnhaven declined dramatically between the 1970-2010 timeframe; today, less than one acre of eelgrass bed remains distributed in patchy areas, with scattered widgeongrass plants in shallow waters. The last year of significant cover was in 2005, when approximately 20 acres of SAV beds were found, mostly along the southern shore of Broad Bay. Record high temperatures caused a large die-back of SAV, particularly eelgrass, in the Chesapeake Bay in summer 2005. This affected the SAV beds in the Lynnhaven River, which lies at the southern end of the Chesapeake Bay. Distribution has been minimal and patchy in the Lynnhaven River since. Considering the distance to the nearest SAV beds that could possibly provide a significant source of drifting propagules, it is unlikely that either eelgrass or widgeongrass will be able to re-colonize the Lynnhaven River to any real extent without intervention. The USACE proposes to restore SAV to the Lynnhaven River. Eelgrass may be locally near the limit of its upper thermal tolerance (Kenneth A. Moore, Jessie C. Jarvis (2008) Environmental Factors Affecting Recent Summertime Eelgrass Diebacks in the Lower Chesapeake Bay: Implications for Long-term Persistence. Journal of Coastal Research: Vol. , Special Issue 55, pp. 135-147.). Overall water temperature data in the Lynnhaven River system(VIMS, 2003) indicate, on average, a slight warming trend, throughout the system. As such, there may be increased risk with relying on the common approach to SAV restoration in the saline portions of Chesapeake Bay, which is set to focus entirely on eelgrass restoration.

One possibility is that the USACE could consider using a more southern stock of eelgrass as a seed source, perhaps a stock native to North Carolina's coastal bays. Such a strain of eelgrass may be more thermally tolerant than the local stock as regional differences in temperature tolerance for *Zostera* has been documented (Beibl and McRoy, 1970), though confirmation of this trait would be required prior to use in the Lynnhaven.

Widgeongrass has not been the focus of SAV restoration efforts in the Chesapeake Bay due to an early decision by various technical work groups to focus on eelgrass instead. Both species are of great ecological value, though there are differences between the two. Eelgrass forms dense beds in typically deeper waters than widgeongrass. Eelgrass tends to form more persistent beds than widgeongrass, which is viewed as a more opportunistic, pioneer species with larger annual fluctuations in bed extent and location than the more stable eelgrass (Cho et al., 2009). Eelgrass transplanting efforts have shown limited promise, though a nearby local success (Naval Amphibious Base, Little Creek) does show that, if the right site is selected, such efforts could work in an area very similar to the Lynnhaven River. However, considering conditions in the modern-day Bay, and the likelihood of further increases in water temperature, it seems prudent to consider a shift in focus to a species that can persist better under what is becoming a warmer temperature regime. This trend has been observed in various areas due to warming water temperatures (Johnson, 2003) and may represent an unavoidable regime shift in species composition due to changing water parameters.

Of note in the Moore et al. (2008) study was that after the die-back induced by high temperatures in summer 2005, eelgrass recovered fasted in areas with higher water quality and more available light. High temperature stress is certainly a factor in eelgrass demise, but it is obviously compounded by additional stressors, such as less-than- optimal light energy levels and/or high nutrient levels, which encourage epiphytic growth on the SAV, inhibiting photosynthesis. These other factors could still inhibit recovery even after the temperature stress is removed. Thus, it is prudent to consider species other than the local strain of eelgrass for SAV restoration, such as the more environmentally-tolerant widgeongrass; we will make such a consideration in our proposed restoration plan. This will increase the chances for success of the SAV.

SAV Benefits

SAV is a highly productive habitat in the estuarine environment (Moore, 2004, Heck et al., 1995, Stevenson, 1988) and as such is of great ecological value. It is known that SAV provides critical nursery habitat for a wide variety of species, including blue crabs, *Callinectes sapidus*, and other crustaceans (Fonseca et al., 1996) as well as excellent foraging habitat for many fish species, including the summer flounder, *Paralichthys dentatus*, which has essential fish habitat (EFH) in the local project area. Many fish species utilize SAV during their larval phases (Olney and Boehlert, 1988). SAV, as noted above, also helps reduce suspended sediments, both by direct action and via stabilizing the bottom over which they grow, preventing resuspension during tidal cycles and storm events. SAV also uptakes organic compounds, particularly nitrogen and phosphorus from the water column, to aid in its own growth. It acts to stabilize bottom sediments, reducing re-suspension rates and improving water clarity.

Benefits for SAV were evaluated on an annual basis and converted into secondary production. During the winter, there is a low standing biomass within the SAV bed, whose own standing crop reaches a low in biomass over the winter. As waters warm in the spring, SAV begins to grow and, along with it, the associated animal biomass within the beds. This growth peaks in the summer, and declines in the fall. When possible, benefits were assessed using estimates developed for local SAV beds (Fredette et al, 1990).

SAV provides protection to nearby estuarine marsh and land by baffling wave energy (Koch and Gust, 1999; Fonseca and Fisher, 1986). This has increased rates of erosion in many nearshore areas once protected by SAV beds, increasing land loss and sediment input into the Chesapeake Bay. A negative feedback loop has been created, where loss of SAV leads to higher rates of erosion, which leads to additional loss of SAV. SAV also acts to increase water clarity in three ways. As water flows over an SAV bed, it is slowed, and TSS tends to precipitate out of the water column into the SAV bed. Second, SAV stabilizes bottom sediments, reducing scouring and related erosion, as well as re-suspension of bottom sediments (Wanless, 1981; Fonseca and Fisher, 1986; Koch and Gust, 1999). Third, SAV actively uptakes nutrients from the water column and competes with phytoplankton for these nutrients. This can lower the frequency and/or intensity of phytoplankton blooms, keeping the water lower in chlorophyll A and clearer due to smaller numbers of phytoplankton.

Loss of SAV directly increases TSS in the water column, and its absence can increase the rate and amount of marine sediments moved by typical current velocities, as well as during storm events. This loss of SAV then further impacts remaining, especially nearby, SAV beds, as they are now subject to increased rates of sediments being deposited in and upon them by typical currents, as well as wave energies and during storm events. This can result in further loss of SAV.

SAV, due to its ability to baffle wave energy, causes TSS to precipitate out of the water column into the SAV bed. Over time, this can result in significant increases in SAV bed elevation (Carpenter and Lodge, 1986). Despite sea level rise, SAV can, in many cases, maintain its position in the water column and continue to survive and even expand. In some cases, SAV beds become so high in the water column that semi-terrestrial wetland plants can colonize the area, eventually leading to a successional process where the SAV bed evolves into a wetland marsh. The increase in sea level rise in the Chesapeake Bay has been greater in recent decades than the ability of SAV to deposit sediments and organic matter sufficient to counter it, and some SAV loss can likely be attributed to this. In these cases, SAV beds often slowly move into formerly more shallow waters, as conditions become more suitable for their growth and survival. We would expect this to occur in the Lynnhaven River as sea level continues to rise over time.

FISH/OYSTER REEFS (EFH)

Background Information

Hard-structure habitat is of great ecological importance in the estuarine environment. It provides attachment surfaces for sessile organisms, cover and shelter for many species of fish and other motile invertebrates such as crabs and shrimp, attachment surfaces for benthic egg masses, produced by a wide variety of species ranging from mollusks (whelks) to fish (toadfish) in the Chesapeake Bay. Such habitat in estuaries generally consists of rocky bottom areas and in many regions, oyster reefs. In the Lynnhaven River, this habitat was historically oyster reefs which, in pre-colonial times, were found both sub- and inter-tidally throughout portions of the river where salinity levels were high enough to support oyster survival and growth. Today, most of these areas are either entirely lost (Chipman, 1948, Haven, 1979) or, in some cases, completely covered with considerable amounts of soft sediments (Dauer, pers. comm.). Extensive bottom surveys conducted in the course of oyster restoration planning (USACE, 2005) discovered two small (< 1 acre) natural oysters reefs, near the confluence of Lynnhaven Bay and the western branch of the Lynnhaven River. These reefs were quite productive, containing approximately 250 adult oysters/square meter, indicating the subtidal hard substrate can still attract significant populations of oysters and other filter feeders and, in turn, attract a wide variety of finfish and shellfish species that utilize reef habitat.

Unlike SAV, artificial reefs do not require a narrow set of environmental parameters in order to function. The main consideration is that the appropriate bottom type be used to place them, as excessive subsidence may result if softer bottom types with high percentages of fines are used. For this aspect of the project, extensive bottom surveys were conducted by the USACE, with additional consultation of sediment data (Dauer) supplementing bottom profile data collected by the USACE. Sites having high percentages of sand (> 80%) were preferentially selected to the extent possible, though some amount of clay is actually desirable as this component tends to make for a less shifting bottom and more conducive to placement of hard structure. Most of the acreage in the Lynnhaven River is currently leased for shellfish production. While most of these areas are not used, they have taken most of the high sand areas in the river. Due to this, several sites have < 80% sand and geotextile matting will be needed to fully support the reef structures. Many areas in the Lynnhaven River system have been severely impacted with terrestrial sediment deposition that resulted from large-scale, rapid urbanization of the watershed, resulting in a thick layer of soft muds over the original sandy bottom, rendering these areas unusable. However, there are still many sandy areas in the system, in particular along the banks in Linkhorn and Broad Bays, the confluence of the eastern and western branch, and within Lynnhaven Bay. Such sites were prioritized as potential fish reef placement locations in the present study. None of these areas are in the low salinity reaches of the upper Linkhorn Bay, eastern or western branches, so it is expected that all fish reefs will be in polyhaline (> 18 ppt) waters and, as such, will be populated heavily by estuarine and marine sessile life such as oysters, mussels, barnacles, sea squirts, bryozoans, and other more marine organisms rather than the much more limited fresh water sessile invertebrate assemblage.

The present study proposes to construct reefs for fish and sessile invertebrate use throughout the Lynnhaven River system. These reefs will likely be constructed out of various types of concrete reef balls and related reef-like structures, though granite rip-rap may be used as well. Artificial reefs have a long history of use (Jensen, 2002, Seaman and Sprague, 1991) worldwide and locally (Virginia Marine Resources Commission Artificial Reef Program, Lipcius and Burke, 2006). The proposed reefs will act as replacement structures for the lost hard structure no longer found in many areas of the Lynnhaven River, and are proposed to be built at considerable more relief from the bottom than the present restored oyster reefs constructed in 2007 and 2008 were built under the USACE oyster restoration program. While there is still some debate over whether or not artificial fish reefs serve to produce more fish (enhancement) or act simply to attract fish (attraction) (Powers et al., 2003, Wilson et al., 2001,), when such habitat is lost and then replaced, it does appear to actually enhance fish production (Wilson et al., 2002, DeMartini et al., 1994, Bohnsack and Sutherland, 1985). As a result, a decision was made to scale the benefits of the proposed fish reefs primarily via the secondary production of benthic macrofauna upon them (Svane and Petersen, 2001, Steimle et al., 2002) which then serve as food sources for motile fish. Additionally, fish reproduction will be enhanced by the hard structure, as many fish species require it to deposit their eggs or their larvae (Stephens and Pondella, 2002) and/or juveniles as well as adults utilize the hard structure for food and shelter (DeMartini et al., 1994).

Fish Reef Benefits

Fish reefs, as stated earlier in the report, will have their benefits scaled primarily by assessing the benthic community that will settle on and grow on the artificial reefs. For fish reef secondary production, the method used was similar to that developed to compensate for the impacts from the proposed Craney Island Eastward Expansion developed using a HEA approach (Ray, 2008 – ERDC-TN-EMRRP-EI-02, Peterson and Associates, 2003), with considerable data available on the benthic community associated with artificial reefs in the Lynnhaven (Burke, 2010) used to help develop the production estimates. It is assumed that benefits to fish will accrue at a rate of

10% trophic level transfer. For example, if a fish reef creates, via secondary production, a biomass of 50 kg, local fish will gain 5 kg in biomass. Fish and large motile crustacean (blue crab primarily) production should be significant (Peterson et al., 2003) and could be as high as 50 kg/m^2 of reef over a 30 year period. Additionally, reef-dependent fish, such as tautog, *Tautoga onitis*, black sea bass, *Centropristis striata,* and the naked goby, *Gobiosoma bosc*, should recolonize the Lynnhaven River. This would result in an increase in species diversity.

SCALLOPS

Background Information

The bay scallop, *Argopecten irradians concentricus,* is a mobile, benthic filter-feeding bivalve mollusk. Unlike most bivalves who have very limited motion via a muscular "foot" primarily used for digging, bay scallops can swim by clapping their valves together rapidly and expelling water in jets from their mantle cavity (Fay et al., 1983). This method of locomotion is used to move, or to escape predators or adverse environmental conditions. Though scallops can be found on other habitat (Pacheco, et al., 2006, Marshall, 1960), SAV beds are their primary habitat. They are rather short-lived for a larger bivalve, typically living one to two years, on average, and are reproductively capable within their first year of life. This is necessary, as scallops are essentially an annual crop. As is typical with most bivalves, their larvae are planktonic, allowing for dispersion over much wider areas than the adults could feasibly travel. The larval phase lasts for approximately 10 days, with settlement occurring in less than two weeks from hatching, on average (Fay et al., 1983). Larvae need higher salinties than adults, and experience mortality when salinity levels drop below 20 ppt. In the areas determined to be suitable for scallop restoration, salinities exceed 20 ppt, with most near the optimal salinity for larval development (Tettlebach and Rhodes, 1981) of 24 ppt (VIMS, 2003). Scallops prefer higher salinity waters within estuaries, doing best as waters approach polyhaline levels (USFWS, 1983). The Lynnhaven River is located near the confluence of the Atlantic Ocean and the Chesapeake Bay and, thus, has the appropriate salinity regime to support both larval and adult scallops. Other water quality parameters, including TSS, meet their life cycle criteria. Scallops are filter feeders throughout their lives, feeding on phytoplankton as both larvae and adults

(Parker 2006, Chipman and Hopkins, 1954). The types of phytoplankton scallops require are in large supply in the Lynnhaven River and throughout the lower Chesapeake Bay. Historically, the only records for scallops in the Chesapeake Bay were anecdotal. There was a small fishery for them, which lasted several years, in nearby coves on Virginia's lower Eastern Shore (Virginia Fish Commission Reports, 1928-1933). This fishery ceased when the massive die-off of SAV occurred in the early 1930's; scallops were extirpated from Virginia's waters at this time. The fishery never occurred in the Lynnhaven River, likely because this river was, at the time, highly productive for oysters. In fact, these oysters commanded the highest market price out of all Bay oyster sources. Little effort would have been made to fish for small numbers of less-valuable scallops, which had very limited market demand at the time. In total, the fishery operated for only four years, and was a fraction of 1% of the oyster fishery at that time. After the collapse of SAV, reports of the presence of scallops were limited and anecdotal. Such reports have indicated the presence of small numbers of scallops immediately outside the Lynnhaven River along the shoreline adjacent to the Lesner bridge. However, it has been noted that in several regions, of which Virginia is one, bay scallops did not recover once the population collapsed due to lack of adults to supply recruitment (Arnold et al., 1988). Without intervention, it is highly unlikely that the bay scallop will ever repopulate suitable habitat in the lower Chesapeake Bay, even if SAV recolonizes the region. The few anecdotal sightings are likely the occasional recruit swept into the Bay. Such a small population is unlikely to be capable of producing any recruitment and is almost certainly a sink for any scallops that recruit to the area.

Scallop Benefits

Bay scallops are a motile filter feeder, with adult scallops having a similar filtration rate compared to that of a market sized (76mm) oyster, with rates as high as 25 liters per hour for adult scallops of 65 mm in size (Chipman and Hopkins, 1954) during the summer, when water temperatures are at their warmest and the metabolic rate of the scallops is at their annual peak. Their average rate was approximately 15 liters per hour. Although the scallop is smaller compared to the oyster, their metabolic rate is higher due to their mobility and active lifestyle, as adult oysters are completely sessile. Similar to oysters, scallops remove TSS and phytoplankton from the water column, retaining the plankton as food and depositing the TSS in their pseudofeces, which is then eliminated and typically becomes incorporated into the sediments. Scallops improve water clarity with their filtration, and this improvement provides additional benefits such as allowing for SAV bed expansion, increased benthic diatom diversity and productivity, and improved filter feeding efficiency for other Bay filter feeders, as less TSS in the water requires less energy for processing and elimination. Therefore, lower TSS levels would allow for increased feeding efficiency for all filter-feeding life in local waters.

Bay scallops play an important role in the estuarine food web. In addition to providing a link between planktonic and benthic food webs via their filter feeding, scallops serve as a source of food for aquatic predators such as green crabs, rock crabs, mud crabs, blue crabs, sheepshead, cow-nose rays, drum fish and others (Seitz et al., 2009, Strieb et al., 1995, Pohle et al., 1991). A restored scallop population will then provide for increased secondary production via their own tissue and then throughout the estuarine food web as they serve as a prey item for a wide variety of nekton. As a conservative measure within the benefits model, scallops were assumed to be able to exist only within SAV beds. Population densities were estimated to be 12 adults scallops per square meter, about 50% of the documented population density from field observations of nearby North Carolina populations (Cooper and Marshall, 1963, Peterson et al., 1996, Seitz et al., 2009). This is a conservative estimate, but as the USACE expects the SAV beds to be a mix of eelgrass and widgeongrass, with the scallops exhibiting a preference for eelgrass, this seems reasonable.

WETLANDS

Background information

Wetlands restoration is extensively done in the Corps of Engineers. In the Lynnhaven River system, extensive development has impacted the wetlands severely. Earlier this century, much of the Lynnhaven wetlands were altered to become farmland. More recently, these areas were developed into urban zones, mostly residential housing as the City of Virginia Beach developed. Today, few wetlands remain, though thin fringes of wetlands are still present to varying extents in all branches of the Lynnhaven River system.

Wetland Benefits

Wetlands are highly productive nearshore habitat. They also stabilize the shoreline, protecting it from erosion. Surface runoff is filtered as it passes through wetlands, reducing nutrient levels, contaminant levels, and sediments prior to reaching the waterway on which the wetlands border. Thus, wetlands are capable of considerable TSS reduction due to their retentive nature and have considerable secondary production.

CALCULATING THE SECONDARY PRODUCTION AND TSS REMOVAL OF RESTORED SCALLOPS, REEFS, WETLANDS AND SAV FOR BENEFITS MODEL

Scallops Secondary Production Calculation

Scallops were taken to be, on average, consisting of a biomass that equates to 13 adults/m^2 of SAV. This is a median value of a reported maximum of approximately 25 adult scallops/m^2 (not counting juveniles, whose biomass is much less than an adult). As such, this number represents less than 50% of the maximum potential biomass, a conservative estimate. A full-sized adult scallop is estimated to be 1 g AFDW. The total biomass produced per acre of scallops is then slightly over 1,000,000 adult scallops at 1,030,000 scallops/acre/year, peaking in the summer months and declining to low values over the winter, where a small population of adults and much larger population of small juveniles overwinters until spring, when warming water temperatures greatly increase growth rates. For our biomass estimate, we take 90% of this, or 229 kg/acre/year of scallop production.

Scallop TSS Reduction Calculation

Scallops do filter TSS; however, they are not as efficient as oysters are in doing so. Reduction was assumed to be slightly less than oysters at 4.83, approximately 75% of the maximum expected rate of oysters. Both species preferentially filter and digest phytoplankton while excreting TSS as semi-solid waste.

Wetlands Secondary Production Calculation

Wetlands secondary production was assumed to be similar to that estimated by Peterson (2003), based on prior work estimating salt marsh primary, secondary, and tertiary production (Kneib, 2001). In this study, Peterson (2003) estimated the secondary herbivore production for *Spartina* marsh wetlands in the nearby Elizabeth River, VA. The numbers that resulted from it have been used for the Lynnhaven River wetlands, which are expected to perform in similar fashion.

The following text is taken from Peterson (2003):
"Kneib (2001) provides a careful synthesis of data on salt marsh primary, secondary, and tertiary production for the purposes of scaling marsh restoration after the Mulberry Phosphate spill near Tampa, Florida. This review provides the necessary scaling approach to estimate production credit for the Craney Island computations. First, we need an estimate of net annual production of the *Spartina* and other large marsh plants in a Chesapeake Bay salt marsh. Kneib's review implies a number of about 1 kg above-ground dry weight m^{-2}, but Robblee (1973) provides a more site-specific figure of about 1270 g m^{-2} for a *Spartina* marsh in the Southern Branch of the Elizabeth River. Second, we need to recognize that about 10% of that is consumed by grasshoppers and other terrestrial insects and herbivores. This production is not counted towards marine productivity. The remaining 90% enters a marine detrital pathway with 55% conversion to fungi, resulting in an estimated 629 g dry weight m^{-2} (1270 x 0.9 x 0.55) annually available to marine invertebrate consumers. Then if we assume that one third of this fungal production is consumed by herbivorous marine invertebrates at the standard ecological efficiency of 10%, then the marsh vascular plant production would be expected to yield 21 g dry weight m^{-2} (629 x 0.33 x 0.1) of herbivorous marine invertebrates."

"To this figure, we need also to add the marine invertebrate production that is derived from the two thirds of the original detritus that was not consumed as fungal biomass (629 x 0.67 = 419 g dry weight m^{-2}). This two thirds of the fungal production enters the sediment bacteria system, where much of it is respired but about 10% (or 42 g dry weight m^{-2}) is converted to bacterial biomass available to herbivorous (detritivorous) marine invertebrates. Bacterial biomass is, in turn, converted to marine invertebrate animal biomass with the standard ecological conversion efficiency of 10%, providing another 4.2 g dry weight of herbivorous marine invertebrates via the bacterial food chains. We further must account for the benthic microalgal production that occurs on the salt marsh. Kneib's (2001) review suggests that this production is about 25% of the above-ground vascular plant production or 318 g dry weight m^{-2} annually. Since the large majority of this material is grazed directly by marine herbivorous invertebrates without going through detrital food chains, this production is expected to yield at the standard 10% conversion efficiency another 32 g dry weight m^{-2} of herbivorous invertebrate production. The total of all three trophic pathways (Table 4) for marsh plant production is thus 57.2 g dry weight m^{-2} (21 + 4.2 + 32). Kneib's synthesis assumes that none of the below-ground production of *Spartina* enters into detrital food chains. This assumption does not hold for marshes in which fiddler crabs or geese are active because they excavate sediments during burrowing and bring up below-ground detritus where bacterial colonization and consumption by detritivores occurs. For *Spartina* marshes, net annual below-ground production is about 4 times as high as above-ground production (K. Boyer, pers. com., Univ. North Carolina). Assuming that about 5% of this below-ground production or 254 g enters the detrital food chains (C. Currin, pers. com, NOAA-Beaufort), and that this is converted to bacterial biomass at 10% efficiency and then to invertebrates at a subsequent 10% efficiency, another 2.5 g dry weight m^{-2} must be added to the total credit for restored salt marsh (Table 4). Consequently, if we assume that a restored salt marsh rapidly serves the full production and trophic transfer functions of a natural salt marsh habitat, then proper credit for restoration should be 59.7 g dry weight m^{-2} of marine herbivores produced annually (Table 4). At 4,046.86 m^2 per acre, this would yield an annual credit of 241.6 kg of marine invertebrate herbivore production per acre of restored salt marsh against which to scale the anticipated loss of annual zooplankton production." For the present study, this 241.6 kg/acre/yr value was selected for the model.

Wetlands TSS Reduction Calculation

"Wetlands are well known to act as sediment traps, and Wetlands TSS was estimated by taking a rather conservative value of the potential sedimentary deposition rate within a vegetated wetland of 2.3 mm/m^2/year. Estimates for sediment deposition rates and/or vertical accretion vary considerably: (4.7 to 6.3 mm/m^2/yr (Armentano and Woodwell, 1975) including sediments and organic material), up to 40 mm sediment/m^2/year in the Bay of Fundy (Chmura, G. L., Coffey, A. and R. Crago), a 1.2 mm/m^2/year of silt in estuarine marshes in the Netherlands over a 170 year period (Olff et al., 1997).A study done in the Lynnhaven River itself on sediment deposition rates in many sub tidal areas (Keuhl, 2008) found that sediment deposition rates in the Lynnhaven River itself varied from a low of 1.2 mm/m^2/year to a high of 8.4 mm/m^2/year on the river bottom. The material settling in the wetland was estimated to be 60% clay, 30% earth and 10% sand. The average weight of these three sediment types per cubic foot varies and is 68 lbs/cu ft dry clay, 100 lbs/cu ft for dry sand and 78 lbs/cu foot for earth. The average dry weight of the expected depositionary material, primarily clays and fine silts with a small sand component, is 74.2 lbs/ cu foot which equal 2,620.35 lbs/m^3. TSS was expected to deposit at a steady rate, as once vegetation is established, it remains constantly on site at high densities (*Spartina* marsh does not die back in winter, though it does become relatively dormant). So, TSS should deposit at a steady pace throughout the year. Based on the 2.3 mm/m^2/year rate of deposition, it is expected that the total weight of sediments deposited in an acre of restored wetlands annually is 11,052 kg/acre/year, which equals 921 kg/acre/month. On a per square meter basis, this equals 2.73 kg/m^2/yr. A study in northern waters of the Chesapeake Bay (Leonard et al., 2001) found that sediment deposition rates were approximately 2.6 mg/m^2/day, providing an annual deposition rate of 9.5 kg (dry weight) sediment/m^2/yr. This high rate occurs within several meters of the marsh edge that is in contact with open water and often greatly declines as you enter marsh interior far from either the water's edge or any tidal gut/creek. These high rates can be more typical on a restoration site if extensive tidal creeks, to improve water flow in the wetland, are incorporated into the design (Reed et al., 1999). The proposed project will do this to the extent practicable. Again, this is a rather conservative estimate, for example, wetlands in Louisiana Coastal marshes can accumulate up to 6.71 kg (dry weight)/m^2/yr (Reed, 1989), due to large sediment inputs from the Mississippi River."

SAV Secondary Production Calculation

For SAV restoration, the impact is primarily to increase the secondary production of what are now barren sand flats (bottom areas with at least 60% sand, the rest can be silt and/or clay) in the Broad Bay and Eastern Branch/Western Branch/Lynnhaven Bay region of the Lynnhaven River system.

For the pre-restoration conditions, Dan Dauer has conducted an extensive benthic survey that included biomass estimation. Taking all samples that met the sand % criteria, we obtain an average ash free biomass of 1.80296 g/m^2. The infauna was dominated by polychaetes, though a significant presence of crustaceans was noted. Diaz and Schaffner (1990) suggest a P:B ratio of 5.7 for crustaceans and 4.9 for polychaetes and 2.9 for mollusks. Taking an average between 4.9 and 5.7 gives us 5.3; multiplying this by the mean biomass of 1.80296 gives us an annual rate of 9.555688 g/m^2/year for the present habitat's benthic production. SAV was estimated to have approximately 200 g/m^2 for small epifauna living on SAV and small infauna (Fredette et al., 1990). Similar studies (Heck et al., 1995) found well over 100 g/m^2/year from SAV beds in Cape Cod, so this 200 g/m^2/year number for the more southern Bay with a longer growing season seems reasonable. At 9.56 g/m^2/yr for pre-restoration versus 200 g/m^2/yr post-restoration (which counts the 9.56 in the 200 total), the increase in benthic productivity is considerable. This amounts to 191.5 g/m2/yr which we round to 192. To this is added secondary production (collectively) of large crustacean, mollusk (hard and soft-shell clam) and fish production due to the SAV bed. Seagrass-based food webs can provide up to 70% of the nutrition of local fish (http://www.spooled.com.au/Article:1208) and the shelter and direct nutrition derived from feeding on animals found within SAV beds can easily produce fish and large crustacean biomass equal or greater than the selected number for this model (Johnson and Heck, 2006). Numbers for these vary widely, so it was decided to double the initial number for a total of 384 g/m2/yr for SAV secondary production to represent the productivity enhancements to finfish, large decapods, and bivalve molluscs other than scallops, which are treated as a separate restoration option in the present study.

SAV TSS Reduction Calculation

TSS removal was estimated based on the biomass of the SAV itself. SAV, due to their buffering effects on water speedcauses TSS to precipitate out of the water. Annual biomass of SAV peaks in summer, with a minimum in above ground vegetation in the winter, so TSS removal follows a similar curve as does biomass (Moore, 2004). SAV is not as effective at precipitating sediments as are wetlands, due to several factors. SAV standing vegetation drops significantly in winter, allowing for re-suspension of sediments. SAV is fully submerged at all times, subject to constant wave action, which inhibits long-term precipitation of sediments. Large animals regularly disturb SAV during foraging, re-suspending sediments that otherwise would have been permanently deposited. Despite this, SAV do retain significant amounts of TSS within beds, modifying the sediments significantly while they simultaneously increase water clarity (Katwyjk et al., 2010). SAV were assigned a value of 150 g of silts deposited annually per square meter

Fish/Oyster (EFH) Reefs Secondary Production Calculation

Secondary production was estimated by consulting the Peterson HEA as well as recent research on oysters colonizing hard substrate in the Lynnhaven River (Burke, 2010). For the high relief reef design, all reefs are well below MLW. A survey of rip rap in the Lynnhaven River in the low intertidal zone had an average peak biomass of 165.02 g AFDW/m^2. Subtidal production was estimated to be 50% of this production rate found in the low intertidal zone, primarily due to higher rates of predation in the subtidal environment. This can be easily observed in similar high-salinity waters (Nestlerode et al., 2007) though survival on alternative materials can be higher than that of shell in such a scenario as was documented in the lower Rappahannock River (Burke, 2010). Based on the available data, 50% seems to be a reasonable number. This gives us a value of 82.5. Applying a P:B ratio of 2.6 (Peterson, 2003) gives us an annual oyster production rate of 214.5 g AFDW/m^2/yr. However, the interior of a reef ball is expected to have a lower rate of production compared to the exterior (Burke, 2010). Interior surfaces will experience lower flow rates, and less available food. Burke (2010) estimated approximately 25% of the biomass on a granite block reef was on the interior surfaces of the granite. Because the reef balls are designed with larger interior spaces and openings for better flow than a small pile of loose granite, we doubled this rate to 50%. Therefore, reef balls will have an annual oyster production rate in AFDW of 147.9 g/m^2/yr. This is a very conservative estimate, and it could be much higher. Subsequent post-construction monitoring will quantify this production. Applying the same ratios used for meiofauna and macrofauna production on an oyster reef developed for the Elizabeth River by Peterson (2003), we arrive at 121.8 g AFDW/m2/yr for reef ball associated meiofauna and 34.7 g AFDW/m^2/yr for reef ball associated macrofauna/m^2/yr for a grand total of 304.4 g AFDW/m^2/yr for high-relief reef balls. The total surface area of the high-relief reef is 14,640 m^2/acre. Therefore, the total production/acre/yr in AFDW is 4457 kg/acre/yr. Low-relief fish reefs have a smaller surface area/acre (11,830 m2/acre) so had a lesser rate of production of 3601 kg/acre/yr.

Fish/Oyster (EFH) TSS Reduction Calculation

TSS reduction was estimated based primarily on the oysters, tunicates, mussels, and barnacles typically found on oyster reefs. There are additional small filter feeders found on oyster reefs, such as tube worms and sponges, but these were not considered. Oyster reefs were found to filter 6.48 times their weight in TSS, on an annual basis, with a peak in summer and low during the winter (Haven and Morales-Alamo, 1966). For the present study, a slightly lower and more conservative number was used, 95% of this or 6.16 times the secondary production on the reefs. It could actually be higher, however, as water in the Lynnhaven River may be slightly warmer than the Chesapeake Bay average, due to its southern location. Filtration (and secondary production) rarely ceases entirely in the Chesapeake Bay, as oyster reefs continued to filter until temperatures dropped below 2.8C (37.04F), a temperature that is rarely reached even in the coldest part of winter in the Bay. This is reflected in the low TSS and secondary production numbers in the winter months, not just for the fish reefs but for the other restoration options. Other studies (Cerco and Noel, 2005, Nelson et al., 2003), have noted significant decreases in chlorophyll A and TSS concentrations in the vicinity of oyster reefs in the field.

Outputs/Index Scores for each Measure

Measure	Secondary Production (kg/acre/yr)	TSS Reduction (kg/acre/yr)	BIBI (1-5)
Wetland creation	242	11,052	4
SAV	1,552	607	5
Scallops	229	1,106	3.5
EFH high relief	4,457	27,393	5
EFH low relief	3,601	22,137	5
Existing Condition/ Without Project	6.41	0	3

Table 1: Ecological Outputs for Various Restoration Options. Note that BIBI were ranked based on another system described in a separate document.

This table, along with the BIBI scores, as seen on pg. 81 of the main report, was used in plan formulation to determine alternative, then the tentatively selected plan. This information in Table 3 was provided to the Virginia Institute of Marine Science to run within their hydrodynamic water quality model. The model runs characterized the potential reductions in chlA and TSS in different regions of the Lynnhaven River as a result of several alternative plans. These represent "best-case" scenarios for each plan.

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USEPA SALT MARSH MODEL DESCRIPTION

USEPA Salt Marsh Model Description

1. INTRODUCTION

The parameters (i.e., TSS, BIBI and secondary production) used to assess benefits gained through the implementation of the other restoration measures are not able to adequately capture environmental improvements produced through the modification of the four wetland sites. Current research suggests that there is no difference in TSS reduction properties in *Phragmites australis* as compared to *Spartina alterniflora*, and the dominant vegetation type of a salt marsh does not significantly impact sediment transport, flow regime, and sediment deposition patterns (Leonard et al., 2002; Chambers et al., 1999). In the case of secondary production, available scientific literature presents little information on the comparative productivity of a *P. australis* versus a *S. alterniflora* dominant marsh. Studies have demonstrated that abundance within *P. australis* is dependent upon species and taxa (Chambers et al., 1999, Meyerson et al. 2000). For example, Krause et al. (1997) found that biomass of insects was high in *P. australis*, while Meyers et al. (2001) found no significant difference in nekton biomass between *P. australis* and *S. alterniflora* marshes. Currently, the shortage of quantitative productivity data makes comparisons of the two systems using secondary production infeasible.

2. MODEL DESCRIPTION

The environmental benefits gained through the restoration/diversification of the wetland sites (Princess Anne, Great Neck North, Great Neck South, and Mill Dam Creek) were determined using a model developed by the USEPA. The EPA model represents the first stand alone assessment tool based on wildlife habitat values of coastal wetlands. The model quantifies salt marsh health and function through the valuation of marsh characteristics and the presence of habitat types. Other tools use marsh functions, such as nutrient removal, to assess wetland sites. However, the creators of this model choose to focus on marsh habitat types, marsh morphology, and landscape setting. This particular marsh function was chosen to be used as the framework for the environmental model for a number of reasons. First, providing wildlife habitat is one of the most important functions shared by all marshes. Salt marshes are thought to be the most productive ecosystems on the world, providing substantial biodiversity, supporting numerous species from all of the major groups of organisms and providing both seasonal and year around habitat for many terrestrial and aquatic species. Next, available habitat is a function that is well suited for assessment. Almost all state and local wetland regulations include habitat protection goals. Of particular interest are wetlands or classes of wetlands that provide habitat for threatened and endangered species. Finally, wetland protection or restoration goals based on wildlife habitat targets are generally well received and understood by the public, particularly when the species of interest, such as large birds and mammals, are included in the project goals.

The USEPA model quantifies habitat values based on marsh characteristics and the presence of habitat types that contribute to use by terrestrial species. Model's developers identified 79 birds, 20 mammals, and 6 amphibian and reptile species that utilize New England salt marsh habitat at some life stage. Habitat requirements of these species were determined through a search of published literature, unpublished reports, anecdotal information from wetland ecologists and personal observations of the model's creators. From the available information, the developers identified common habitat types associated within salt marshes, or those that were reported as being used by at least 3 bird or mammal species. These habitat types, as well as the habitat requirements of salt marsh fauna, form the basis of the salt marsh assessment model.

The model consists of eight wetland and landscape components that are used to assess and evaluate salt marsh wildlife habitat values (Figure 1). Several of the components are directly based on the different habitat types found in and around marshes or ecosystems that are linked to salt marshes. Other components reflect the anthropogenic alteration of these habitats. The remaining components take into account the size, morphology, and landscape positions of the marsh, which may be important to territorial species and those that require adjacent upland habitats. The eight components are (1) marsh habitat types, (2) marsh morphology, (3) marsh size, (4) degree of anthropogenic modification, (5) vegetative heterogeneity, (6) surrounding land use, (7) connectivity, and (8) vegetation types. Each component, in turn, consists of several categories. For example, the "Habitat Type" component consists of ten categories including shallow open water, tidal flats, pannes, wooded islands, and low marsh. A complete description of each habitat component and the overall framework of this model are included in McKinney and Wigand (2006) paper.

Component	Categories	Criteria
I. Salt Marsh Size Class	Very small (under 5 ha)	Marsh area
	Small (5 – 25 ha)	
	Medium-sized (26 – 125 ha)	
	Large (126 – 200 ha)	
	Very large (over 200 ha)	
II. Salt Marsh Morphology	Salt meadow marsh	Marsh morphology
	Meadow / fringe marsh	
	Wide fringe marsh	
	Narrow fringe marsh	
	Marine fringe marsh	
III. Salt Marsh Habitat Types	Shallow open water	Presence or abundance
	Tidal flats	
	Low marsh	
	Trees overhanging water	
	High marsh	
	Pools	
	Pannes	
	Wooded islands	
	Marsh-upland border	
	Phragmites	
IV. Extent of Modification	Little to no ditching	Degree of modification
	Moderate ditching	
	Severe ditching	
	Little to no tidal restriction	
	Moderate tidal restriction	
	Severe tidal restriction	
V. Salt Marsh Vegetation	Aquatic plants	Presence or abundance
	Emergents	
	Shrubs	
	Trees	
	Vines	
VI. Vegetative Heterogeneity	High heterogeneity	Number of habitat edges
	Moderate heterogeneity	
	Low heterogeneity	
VII. Surrounding Land Cover	Open water	Presence or area
	Natural land	
	Maintained open land	
	Developed land	
VIII. Connectivity	Sand or cobble beach	Presence or area
	Coastal dunes or overwash	
	Other salt marsh wetland	
	Brackish wetland or pond	
	Freshwater wetland or pond	
	Upland meadow	
	Upland forest	

FIGURE 1: WETLAND ASSESSMENT COMPONENTS AND THEIR ASSOCIATED CATEGORIES OF THE USEPA MODEL.

The model user assigns a rating of low, moderate, high or absent to each model category. The rating is given a numerical score and a weighting factor to reflect faunal habitat requisites, which can be found in Figure 2. For example, one category of the habitat component involves the presence of shallow water. If open shallow water habitat makes up >20% of the marsh, the category is given a numeric score of "5". If open shallow water habitat is absent from a salt marsh, the category is given a "0". The value of each category is multiplied by a weighting factor. The output produced by the USEPA model is a numerical score, an overall relative wildlife habitat assessment score for the marsh, which is calculated by summing subtotals for each of eight habitat components of the model (McKinney et al. 2009a). The maximum wildlife habitat assessment score possible from the USEPA model is 784, with small, impaired marshes receiving values below 100. The values and weighting factors assigned to each model component are given in the table below ((McKinney et al. 2009a).

The scores and weighting factors for each component were developed and tested on a group of 16 salt marshes in Narragansett Bay, Rhode Island. The study and resulting conclusions are described in two peer reviewed papers; "Assessing the wildlife habitat value for New England salt marshes: I. Model and application" and "Assessing the wildlife habitat value of New England salt marshes: II. Model testing and validation".

a) Pre-classification components

Component	Category	Weighting factor	Criteria (value) High (5)	High/mod. (4)	Moderate (3)	Mod./low (2)	Low (1)
Size class	–	10	> 200 ha	126–200 ha	26–125 ha	5–25 ha	< 5 ha
Morphology	–	10	Salt meadow	Meadow/fringe	Wide or marine fringe	–	Narrow fringe

b) Assessment components

Component	Category	Weighting factor	Criteria (value) High (5)	Moderate (3)	Low (1)	Absent (0)
Habitat type	shallow open water	7	>20% of marsh unit	10–20% of marsh unit	<10% of marsh unit	absent
	tidal flats	8	>30% of marsh unit	5–30% of marsh unit	<5% of marsh unit	absent
	low marsh	8	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	trees overhanging water	5	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	high marsh	8	>40% of marsh unit	5–40% of marsh unit	<5% of marsh unit	absent
	wooded islands	6	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	phragmites	4	>3% of marsh unit	1–3% of marsh unit	<1% of marsh unit	absent
	pools	8	>10 pools/ha	2–10 pools/ha	<2 pools/ha	absent
	pannes	5	>10 pannes/ha	2–10 pannes/ha	<2 pannes/ha	absent
	marsh-upland border[a]	8				
	width		width >8 m	width 2–8 m	width <2 m	–
	length		>65% of perimeter	50–65% of perimeter	<50% of perimeter	–
	composition		>70% shrubs	50–70% shrubs	<50% shrubs	–
Anthropogenic modification	ditching	9	little to no ditching	moderate ditching	severe ditching	–
	tidal restriction	7	little to no restriction	moderate restriction	severe restriction	–

FIGURE 2: THE VALUES AND WEIGHTING FACTORS FOR EACH HABITAT CATEGORY USE IN THE USEPA MODEL

Vegetation	aquatic plants	2	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	emergents	3	>90% of marsh unit	75–90% of marsh unit	<75% of marsh unit	absent
	shrubs	3	>20% of marsh unit	5–20% of marsh unit	<5% of marsh unit	absent
	trees	4	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	vines	1	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
Vegetative heterogeneity	–	6	5 edge habitats	3–4 edge habitats	1 or 2 edge habitats	–
Surrounding land use	open water	6	>35% of buffer[b]	25–35% of buffer	<25% of buffer	–
	natural land	9	>25% of buffer	10–25% of buffer	<10% of buffer	–
	maintained open	5	<5% of buffer	5–15% of buffer	>15% of buffer	–
	developed land	9	<5% of buffer	5–35% of buffer	>35% of buffer	–
Connectivity[c]		9				
	habitat types in buffer[d]		>4	3–4	1–2	–
	average size		>3 ha	1–3 ha	<1 ha	–
	proportion of buffer		>30% of buffer	15–30% of buffer	<15% of buffer	–

FIGURE 2: THE VALUES AND WEIGHTING FACTORS FOR EACH HABITAT CATEGORY USE IN THE USEPA MODEL (Cont'd).

3. MODEL REQUIREMENTS

The USEPA designed the model to be an easily accessible tool to be used by field biologists and resource managers to perform office-based assessments that could be run in a relatively short amount of time using readily available data and software. The model designers intended that output produced by the model would be used to make planning and management decisions, such as "(1) prioritizing marshes for protection and restoration, (2) identify ecologically important marshes that could potentially harbor high biodiversity, and (3) monitor changes in habitat value over time, for example during the course of salt marsh restoration" (McKinney et al. 2009a).

The input data necessary for the application of the model is "at a minimum, aerial photographs showing each salt marsh to be assessed and the surrounding landscape at least 1km around each site are required to carry out the assessment. Digital land use and land cover in a GIS will aid in determining surrounding land use and associated habitats. Office-based aerial photo delineation to assess habitat type, vegetative structure, and vegetative heterogeneity should, if possible, be supplemented with field assessment" (USEPA, 2008).

Software and hardware required to run the EPA model are commonly available in an office setting. A personal computer increases the ease of using the model (in order to run a spreadsheet program); however it is not necessary to run the model. An Excel or any simple spread sheet software package can be used to calculate habitat assessment scores. The results of the USEPA model are extremely easy to export into a report since output data is produced using a spreadsheet program. The entire spread sheet can be imported into the body of the report or individual wildlife habitat assessment scores can be easily included in the text. If the user does not have access to a computer, a hand calculator can also be used to calculate habitat values. These calculations could even be completed using paper and pencil, if a researcher was in the field and had the corresponding values to each habitat component.

The model is easily accessible through the website of the Atlantic Ecology Division of the USEPA. The model is described in three papers, all of which are available on the USEPA website. A matrix, including the assessment components, and their associated weighting factors and scores, is available in McKinney and Charpentier's paper entitled "Assessing the wildlife habitat value of New England salt marshes: I. Model and application" (Figure 2). The paper was published in 2009 in the journal Environmental Monitoring and Assessment. An Excel spreadsheet which calculates individual wildlife habitat assessment scores is also available in the USEPA website, which is listed below. These calculations can be easily reproduced and verified using any spread sheet software or with a handheld calculator.

http://www.epa.gov/aed/html/research/wetland/saltmarsh/

There is no formal training associated with the USEPA model. Since the basis of the model is to assess marsh quality through available habitats, the model user must have an understanding of and the ability to recognize habitat types present in a salt marsh. The user must be able to differentiate, either from aerial photography or through field visits, vegetative structures and habitat types. The user must also be able to estimate the extent of habitat or vegetation types that make up each study site. The calculations used to produce the habitat scores are relatively simple, so users only need an understanding of basic algebra. If a spreadsheet program is available, then the user may also need to program functions and input data into a spreadsheet in order to calculate habitat values.

4. APPLICATION OF THE USEPA MODEL DURING THE LYNNHAVEN RIVER BASIN STUDY

The USEPA model was used to calculate environmental benefits that would be derived from restoration and diversification efforts at four wetland sites within the Lynnhaven River Basin throughout the 50 year lifespan of the Lynnhaven River Basin Restoration Project. The model was run twice for each site in order to produce the "Without Project" and "With Project" values. The data used to quantify the "With" and "Without Project" condition values was obtained through aerial photography, collected in 2007, and site visits to all four wetland sites during the winter of 2009.

The "Without Project" condition was determined using the current conditions found at each project site. The assumption intrinsic in the uses of current conditions when developing the "Without Project" condition is that the plant community is in equilibrium and the marsh will remain relatively stable over time. The inherent weakness of this assumption is that it does not account for possible disturbances (e.g. construction and development adjacent to the marsh, sea level rise) that have the potential to alter site conditions.

"With Project" values were developed using anticipated site conditions once restoration efforts have been completed. The future site conditions were determined using site conditions present at two high-quality, reference sites and the best professional judgment of the USACE biologist. The inherent weakness of forecasting future conditions is that there is no way to guarantee that optimal conditions will be established at the wetland sites. This uncertainty can be mitigated with the establishment of monitoring and adaptive management programs, as is required by USACE policy and has been included in the Lynnhaven Project report.

The difference between the "With" and "Without Project" conditions represents the environmental benefits that will be gained through the restoration of the wetland sites. Benefit gains were due to changes to only three model components, "Habitat Type," "Vegetation," and "Vegetative Heterogeneity." The "Habitat Type" component assesses the presence of 10 distinct microhabitats found within a salt marsh (i.e. shallow open water, tidal flats, pannes, trees over hanging water, high marsh, phragmites, pools, marsh-upland border, wooded islands, and low marsh) by assigning values and weighting factors to the percentage of each microhabitat present at the site. The model also assigns value to the composition of the salt marsh plant community through the "Vegetation" component. The percentage of five plant groups (aquatic plants, emergents, shrubs, trees, and vines) within the marsh unit is captured in this component. The "Vegetative Heterogeneity" component accounts for the abundance and diversity of vegetative edges. An "edge" is defined as either an interface between two adjacent plant groups, as described in the "Vegetation" component, or between a plant group and a marsh habitat type, as described in the "Habitat Type" component.

Due to limits in project size and scope, certain model components were not affected by the proposed restoration treatments. For example, the restoration effort will have no effect on surrounding land use, marsh size, marsh morphology, or anthropogenic modification (e.g. tidal restriction and ditching). The efforts also will not affect marsh connectivity, which is "the functional relationship between adjacent habitats arising from their spatial distributions and the movement of organisms" (McKinney and Wigand, 2006). As a result, the values assigned to these components remained constant in both the "Without Project" and "With Project" conditions.

The spreadsheets completed for the wetland and reference sites are included at the end of this document. The scores described in this report have been summarized in Table 2, which is also placed at the end of the discussion.

The Great Neck North site scored highest of all four sites in the "Without Project" condition. It received a score of 384, which is 49 percent of the maximum possible value. This score resulted from the marsh morphology because the site falls into the "Salt Meadow/Fringe" category, which is a configuration that is considered highly valuable in the USEPA model. The site also scored highly because of the small amount of anthropogenic modification (no tidal constriction and little to no ditching) and relatively high levels of connectivity and vegetative heterogeneity. The site received a score of 436 for the "With Project" condition, which is 56 percent of the maximum, representing a 52 point gain. The increase was due to two model components. The "Habitat Type" component value increased from 107 in the "Without Project "condition to 147 in the "With Project" condition, while the "Vegetative Heterogeneity" component increased from a value of 18 to 30. Average annual benefits were calculated by subtracting the score of "Without Project" condition from the "With Project" condition. In the case of the Great Neck North site, the 52 units would be gained annually if restoration efforts were completed.

The Princess Anne site received the second highest "Without Project" condition score and the largest net benefit gain from restoration efforts. The site warranted 304 points for the "Without Project" condition and 389 points for the "With Project" condition. The site is a relatively small fringe marsh located in a highly developed area; therefore it received low scores for the “Size Class,” “Morphology,” “Connectivity,” and “Surrounding Land Use” components. However, the site is not ditched and has little to no tidal restriction. Even though *Phragmites* dominates the lower marsh, the site exhibits a relatively high level of vegetative heterogeneity. The site received high scores on the “Vegetative Heterogeneity” and “Habitat Type” components. The model components which accounted for the change between the “With Project” and “Without Project” conditions were the same as for the Great Neck North site. “Habitat Type” increased from 107 to 178, and “Vegetative Heterogeneity” increased from 18 to 30. The environmental impact resulting from the restoration of the Princess Anne site is predicted to be the greatest of all of the four wetland sits, with an average annual gain of 85 points.

The current conditions at the Great Neck South site resulted in a low “Without Project” condition score of 286, which is 36 percent of the possible maximum score. The marsh is a relatively large “salt meadow/fringe” exhibiting some habitat diversity within the buffer zone surrounding the site, so it received high values for the “Morphology” and “Connectivity” components. The site consists almost entirely of *Phragmites*, so “Habitat Type” and “Vegetative Heterogeneity” scores were low. The “With Project” conditions increased 75 points, to a score of 361. The components that were responsible for the change were “Habitat Type” (from 53 to 113), “Vegetative Heterogeneity” (from 6 to 18), and “Vegetation” (from 20 to 23). The environmental benefit gained through the restoration of the Great Neck South site is estimated to be 75 points.

The final site, Mill Dam Creek, had the lowest values both prior to and after the completion of the restoration efforts, earning 282 for the “Without Project” condition (36 percent of the total available score) and 348 for the “With Project” condition, only 44 percent of the possible maximum. The sites received low scores for most model components in its current conditions because the marsh is a small, fringe marsh that is completely dominated by common reed. The “Size Class,” “Morphology,” and “Vegetative Heterogeneity” components received the lowest values, only 20 percent of the maximum available value. The change in condition between “With Project and “Without Project” was observed in the “Habitat Type” (from 94 to 148) and the “Vegetative Heterogeneity” (from 6 to 18) components. The benefits gained from project implementation were 66 points.

The environmental benefits calculated using the EPA model can be found in the following table for each of the wetland restoration sites. The spreadsheets, which include the individual component values for each site are included at the end of this document.

Table 1. WETLANDS WITH PHRAGMITES ERADICATION SITES AVERAGE ANNUAL BENEFIT

Wetlands with Phragmites Eradication Site	Average Annual Wetland Benefits (With Project – Without Project Condition)
Princess Anne High School	85
Mill Dam Creek	66
Great Neck North	52
Great Neck South	75
No Action Plan	0

Limitations of the USEPA Model

One limitation of the model, the intended geographic range, led to consideration of the appropriateness of the model for the Lynnhaven Project. The model was designed to be used specifically on coastal salt marshes of New England, from Maine to New Jersey. The Lynnhaven River Basin Restoration Project is located in Virginia, outside of the proposed range of the model. Upon analysis of the model, a number of compelling arguments were found that supported its use for the Lynnhaven Project.

First, the model developers included a very general description of a New England marsh in the paper describing the model's framework. These wetlands were characterized as being "typically small and receive low suspended sediment loads from relatively small drainage basins, resulting in predominately organic peat substrates. Salt marsh morphology in this region reflects the relatively steep slope of New England estuarine coastlines, as well as the influence of development and modification by humans" (McKinney and Wigand 2006). Salt marshes within the New England region vary widely and an assessment tool must take into account naturally occurring variations in order to be effective. Although there may be some differenced between salt marshes of the two regions, such as peat/sediment ratios present in marsh substrates and tidal range, the marshes share more traits (e.g. plant community composition, habitat types and ecological functions) than differences and the habitat conditions found at the Lynnhaven Project wetland sites fall within the natural range of variation found salt marshes of New England.

Second, the model was developed using species that are found both in New England and Virginia. The model's framework is based on the habitat needs of 105 different terrestrial species (79 birds, 20 mammals, and 6 reptiles and amphibians). Of course, there are differences in wildlife population composition found in the marshes of New England and those located in Virginia. However, almost all of the species (96%) used to develop the USEPA model occur within Virginia and can be found utilizing salt marsh habitat of the state. Only four species (swamp sparrow, snowy owl, fisher and New England cottontail) do not have ranges that include territory within Virginia.

Finally, the model was also used to evaluate two reference sites, in addition to the four proposed project sites. The assessment results were examined to see if the model could differentiate between impaired and unimpaired salt marshes located in the Lynnhaven River basin. The two reference site earned scores of 447 points (57% of the maximum possible score) and 552 points (70% of the maximum possible score). The impaired sites earned scores between 282 (36% of the maximum possible score) and 384 (49% of the maximum possible score). The model was able to capture differences between impaired and unimpaired sites and it produced habitat values that were similar to the qualitative rankings of each site by the USACE staff working on the Lynnhaven Project. Therefore it was judged to be a useful and appropriate tool to predict potential benefits gained between the "Without Project" and "With Project" conditions.

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Table 2: The scores given to each wetland and reference site using the USEPA Model in the Lynnhaven River Basin Restoration Study.

Site:	**Princess Anne**		**Mill Dam Creek**		**Great Neck South**		**Great Neck North**		**Ref Site 1**	**Ref Site 2**
Project Condition:	**Without Project**	**With Project**	**Without Project**	**With Project**	**Without Project**	**With Project**	**Without Project**	**With Project**		
Habitat Component										
Size Class	10	10	10	10	20	20	20	20	10	20
Morphology	10	10	10	10	30	30	40	40	30	50
Habitat Type	107	178	94	148	53	113	107	147	118	145
Modification	80	80	45	45	45	45	80	80	62	80
Surrounding Land	41	41	67	67	85	85	75	75	133	145
Connectivity	9	9	27	27	27	27	27	27	45	45
Vegetative Heterogeneity	18	30	6	18	6	18	18	30	18	30
Vegetation	29	31	23	23	20	23	17	17	31	37
Total:	304	389	282	348	286	361	384	436	447	552
Percent of Maximum:	39%	50%	36%	44%	36%	46%	49%	56%	57%	70%
Environmental Benefit:		85		66		75		52	-	-
(With project - Without Project Condition)										

Site: Princess Anne
Condition: Without Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	> 200 ha	126-200 ha	26-125 ha	5-25 ha	< 5 ha	Total
Size Class	10					X	10
	Weight	Salt meadow	Meadow / fringe	Wide fringe; marine fringe		Narrow fringe	
Morphology	10					X	10

Beneficial categories:

	Score:	0	1	3	5	
	Weight	Absent	Low	Moderate	High	Total
Habitat Type						107
Shallow open water	7			X		21
Tidal flats	8	X				0
Low marsh	8			X		24
Trees overhanging water	5		X			5
High marsh	8		X			8
Wooded islands	6			X		18
Pools	8		X			8
Pannes	5	X				0
Marsh upland border	8		X			8
Phragmites	4				X	20
Vegetation						29
Aquatic plants	2	X				0
Emergents	3				X	15
Shrubs	3			X		9
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						27
Open water	6			X		18
Natural land	9		X			9
Connectivity	9		X			9
Vegetative Heterogeneity	6			X		18
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						80
Ditching	9		X			45
Tidal restriction	7		X			35
Surrounding Land						14
Maintained open	5				X	5
Developed land	9				X	9

Site: Princess Anne
Condition: With Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10					X	10
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10					X	10

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						178
Shallow open water	7				X	35
Tidal flats	8		X			8
Low marsh	8				X	40
Trees overhanging water	5	X				0
High marsh	8			X		24
Wooded islands	6			X		18
Pools	8			X		24
Pannes	5		X			5
Marsh upland border	8			X		24
Phragmites	4	X				0
Vegetation						31
Aquatic plants	2		X			2
Emergents	3			X		9
Shrubs	3				X	15
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						27
Open water	6			X		18
Natural land	9		X			9
Connectivity	9		X			9
Vegetative Heterogeneity	6				X	30
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						80
Ditching	9		X			45
Tidal restriction	7		X			35
Surrounding Land						14
Maintained open	5				X	5
Developed land	9				X	9

Site: Mill Dam Creek
Condition: Without Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10					X	10
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10					X	10

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						94
Shallow open water	7			X		21
Tidal flats	8	X				0
Low marsh	8			X		24
Trees overhanging water	5			X		15
High marsh	8	X				0
Wooded islands	6		X			6
Pools	8	X				0
Pannes	5	X				0
Marsh upland border	8		X			8
Phragmites	4				X	20
Vegetation						23
Aquatic plants	2	X				0
Emergents	3				X	15
Shrubs	3		X			3
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9	X		X		27
Vegetative Heterogeneity	6		X			6
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						45
Ditching	9	X				45
Tidal restriction	7				X	0
Surrounding Land						34
Maintained open	5		X			25
Developed land	9				X	9

Site: Mill Dam Creek
Condition: With Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10					X	**10**
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10					X	**10**

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						**148**
Shallow open water	7				X	35
Tidal flats	8	X				0
Low marsh	8			X		24
Trees overhanging water	5			X		15
High marsh	8	X				0
Wooded islands	6		X			6
Pools	8			X		24
Pannes	5	X				0
Marsh upland border	8			X		24
Phragmites	4				X	20
Vegetation						**23**
Aquatic plants	2	X				0
Emergents	3			X		9
Shrubs	3			X		9
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9			X		27
Vegetative Heterogeneity	6			X		18
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						45
Ditching	9	X				45
Tidal restriction	7				X	0
Surrounding Land						34
Maintained open	5		X			25
Developed land	9				X	9

Site: Great Neck South
Condition: Without Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10				X		20
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10			X			30

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						53
Shallow open water	7		X			7
Tidal flats	8	X				0
Low marsh	8		X			8
Trees overhanging water	5		X			5
High marsh	8	X				0
Wooded islands	6	X				0
Pools	8		X			8
Pannes	5		X			5
Marsh upland border	8	X				0
Phragmites	4				X	20
Vegetation						20
Aquatic plants	2	X				0
Emergents	3				X	15
Shrubs	3	X				0
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9			X		27
Vegetative Heterogeneity	6		X			6
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						45
Ditching	9	X				45
Tidal restriction	7				X	0
Surrounding Land						52
Maintained open	5		X			25
Developed land	9			X		27

Site: Great Neck South
Condition: With Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10				X		20
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10			X			30

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						113
Shallow open water	7			X		21
Tidal flats	8	X				0
Low marsh	8		X			8
Trees overhanging water	5		X			5
High marsh	8	X				0
Wooded islands	6		X			6
Pools	8			X		24
Pannes	5		X			5
Marsh upland border	8			X		24
Phragmites	4				X	20
Vegetation						23
Aquatic plants	2	X				0
Emergents	3			X		9
Shrubs	3			X		9
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9	X		X		27
Vegetative Heterogeneity	6			X		18
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						45
Ditching	9	X				45
Tidal restriction	7				X	0
Surrounding Land						52
Maintained open	5		X			25
Developed land	9			X		27

Site: Great Neck North
Condition: Without Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10				x		20
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10		X				40

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						107
Shallow open water	7		X			7
Tidal flats	8		X			8
Low marsh	8				X	40
Trees overhanging water	5		X			5
High marsh	8	X				0
Wooded islands	6		X			6
Pools	8		X			8
Pannes	5		X			5
Marsh upland border	8		X			8
Phragmites	4				X	20
Vegetation						17
Aquatic plants	2	X				0
Emergents	3		X			3
Shrubs	3			X		9
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9			X		27
Vegetative Heterogeneity	6			X		18
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						80
Ditching	9		X			45
Tidal restriction	7		X			35
Surrounding Land						42
Maintained open	5			X		15
Developed land	9			X		27

Site: Great Neck North
Condition: With Project
Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10				X		20
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10		X				40

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						147
Shallow open water	7		X			7
Tidal flats	8		X			8
Low marsh	8				X	40
Trees overhanging water	5		X			5
High marsh	8		X			8
Wooded islands	6		X			6
Pools	8			X		24
Pannes	5		X			5
Marsh upland border	8			X		24
Phragmites	4				X	20
Vegetation						17
Aquatic plants	2	X				0
Emergents	3		X			3
Shrubs	3			X		9
Trees	4		X			4
Vines	1		X			1

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						33
Open water	6		X			6
Natural land	9			X		27
Connectivity	9			X		27
Vegetative Heterogeneity	6				X	30
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						80
Ditching	9		X			45
Tidal restriction	7		X			35
Surrounding Land						42
Maintained open	5			X		15
Developed land	9			X		27

Site: Reference Site #1

Pre-classification:

	Score:	5	4	3	2	1	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10					X	10
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10			X			30

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						118
Shallow open water	7	X				0
Tidal flats	8	X				0
Low marsh	8				X	40
Trees overhanging water	5		X			5
High marsh	8			X		24
Wooded islands	6		X			6
Pools	8	X				0
Pannes	5			X		15
Marsh upland border	8			X		24
Phragmites	4		X			4
Vegetation						31
Aquatic plants	2	X				0
Emergents	3			X		9
Shrubs	3			X		9
Trees	4			X		12
Vines	1		X			1

Beneficial categories:

	Score:	0	1	3	5	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						63
Open water	6			X		18
Natural land	9				X	45
Connectivity	9	X			X	45
Vegetative Heterogeneity	6			X		18
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						62
Ditching	9			X		27
Tidal restriction	7		X			35
Surrounding Land						70
Maintained open	5		X			25
Developed land	9	X				45

Site: Reference Site #2

Pre-classification:

	Score:	**5**	**4**	**3**	**2**	**1**	
	Weight	**> 200 ha**	**126-200 ha**	**26-125 ha**	**5-25 ha**	**< 5 ha**	**Total**
Size Class	10				X		20
	Weight	**Salt meadow**	**Meadow / fringe**	**Wide fringe; marine fringe**		**Narrow fringe**	
Morphology	10	X					50

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Habitat Type						145
Shallow open water	7			X		21
Tidal flats	8		X			8
Low marsh	8				X	40
Trees overhanging water	5		X			5
High marsh	8			X		24
Wooded islands	6		X			6
Pools	8		X			8
Pannes	5		X			5
Marsh upland border	8			X		24
Phragmites	4		X			4
Vegetation						37
Aquatic plants	2	X				0
Emergents	3			X		9
Shrubs	3				X	15
Trees	4			X		12
Vines	1		X			1

Beneficial categories:

	Score:	**0**	**1**	**3**	**5**	
	Weight	**Absent**	**Low**	**Moderate**	**High**	**Total**
Surrounding Land						75
Open water	**6**				X	30
Natural land	**9**				X	45
Connectivity	**9**	X			X	45
Vegetative Heterogeneity	**6**				X	30
Detrimental categories:						
	Score:	**5**	**5**	**3**	**1**	
	Weight	**Absent**	**Low / no**	**Moderate**	**High**	**Total**
Modification						80
Ditching	**9**		X			45
Tidal restriction	**7**		X			35
Surrounding Land						70
Maintained open	**5**	X				25
Developed land	**9**	X				45

PHASE I HTRW ENVIRONMENTAL SITE ASSESSMENT

Summary
A phase 1 Environmental Site Assessment (ESA) was performed at the four wetland restoration sites proposed for the Lynnhaven River Basin Restoration Study. The site assessment included a site reconnaissance and review of government and historical documents relating to the sites and surrounding areas. All practices conformed to the recommendations of American Society of Testing Materials (ASTM) standard 1527-00 "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process."

All four sites are estuarine wetlands located in the Lynnhaven River Basin. No areas of concern were identified.

Document and database reviews indicated a low probability that a recognized environmental condition exists at the sites due to contamination from surrounding properties. There are no structures located with the wetland sites and no history of use because of the nature of the sites (estuarine wetlands) that would pose a threat of environmental hazard to people living adjacent to the project sites or the Lynnhaven River Basin ecosystem.

1.0 INTRODUCTION

This report summarizes the findings of the Phase I Environmental Site Assessment (ESA) at the four wetlands restoration/diversification sites proposed for the Lynnhaven River Basin Restoration Study. The ESA was performed in accordance with the recommended practices described in the ASTM Standard E 1527-00: "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process." The purpose of the ESA is to determine the existence of or potential for any recognized environmental conditions. A recognized environmental conditions is defined as :"the presence or likely presence of any hazardous substances or petroleum products on the property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, ground water, or surface water of the property" (ASTM E1527-00)

The ESA was only performed on the wetland project areas and not on the areas proposed for the other restoration measures due to the fact that these sites are subaquatic and the proposed treatments will not involve the removal of sediment.

The ESA for the four wetland sites was conducted by performing a site reconnaissance and records review. The site conditions (e.g. dense vegetation, deep mud and limited access due to private property and the nature of the sties) limited the reconnaissance that could be completed at the sites. However, the edges of the wetland were investigated as much as physically possible and the areas were viewed from adjacent sites of higher elevation, such as bridges and overpasses. Detailed notes and photographs were taken to corroborate any observations made.

Records were obtained from government and historical sources. Government records included searches of entities or conditions surrounding the property. Historical records were reviewed to determine all past uses on the property and any pertinent practices in the surrounding area that indicated a recognized environmental condition on the property.

2.0 SITE DESCRIPTION AND SURROUNDING PROPERTIES

2.1 Princess Anne Site

The Princess Anne site (PA) is "half moon" shaped, with a fringe marsh, and approximately 3.82 acres in size (Figure 1). The site is located northeast of Virginia Beach Town Center, in a highly developed area of the city. The regions south and west of the site are highly urbanized, consisting of large, multistoried buildings and impervious surfaces, such as parking lots and roadways. The areas situated to the north and east of the PA site are made up of residential neighborhoods of single family housing units.

The western edge of the PA site flanks Princess Anne High School and Thalia Lynn Baptist Church. A 50 to 100-foot wide forested buffer zone separates the marsh from the large parking lots, buildings, and recreational fields of the school and church. Thurston Branch runs along the eastern edge of the site. On the opposite shore across from the PA site, a single line of trees separates Thurston Branch from Thalia Elementary School. The school property is comprised of numerous buildings, a parking lot, and maintained lawn. A drainage channel separates the PA site from another fragment of salt marsh approximately 1 acre on the site's southern edge.

2.2 Great Neck North Site

Great Neck North (GNN) is the largest wetland site included in the Lynnhaven Restoration Project, consisting of 19.98 acres of tidal marsh (Figure 2). The GNN site is a long, narrow salt meadow running north to south. It is approximately .33 miles in length, and varies between .05 and 0.16 miles in width. The northern edge of the GNN site is defined by a bridge allowing Route 264/ Virginia Beach Expressway to cross the channel which connects the marsh to Linkhorn Bay. Tidal flushing of the site is not restricted by the bridge. The southern limit of the site is established by Virginia Beach Boulevard. A Dominion Power right-of-way defines the entire western edge of the site. The upland beyond the right-of-way is made up of a narrow, forested border, and the buildings, lawns, and paved parking lots of the two apartment complexes and the self storage business that have been constructed adjacent to the site. The eastern side of the GNN site is developed with an apartment complex, a police academy, a trailer park, and a small number of single family houses. Most of the eastern edge has a narrow buffer zone separating the marsh from the developed upland. Beyond the buffer, the upland adjacent to the site is composed of maintained lawns, structures, and impervious surfaces.

2.3 Great Neck South Site

Great Neck South (GNS) site is connected to GNN via two, small culverts that run under Virginia Beach Boulevard (Figure 3). The culverts that link the sites restrict tidal flow between the two marshes. The GNS site is a large (13.68 acres), narrow salt meadow running from north to south. The site has similar dimensions as GNN, being about 0.32 miles in length and varying between 0.05 and 0.16 miles in width. The northern edge of the site is defined by Virginia Beach Boulevard and the southern edge is marked by a railroad trestle. The Dominion Power right-of-way present at the GNN site continues along the entire western edge of the GNS site. Beyond the right-of-way, the land adjacent to the western edge contains two large commercial properties, one of which is an auto salvage yard. This area consists of large parking lots, commercial buildings, wooded uplands, and a containment pool. The eastern edge of the GNS site contains two relatively large wooded areas, one being approximately 7.5 acres in size and the other being about 5.5 acres. Three commercial properties are also located in the eastern tract, including two self storage businesses. The area consists of wooded uplands, impervious surfaces, commercial buildings, maintained lawn, and about 1.5 acres of bare earth.

2.4 Mill Dam Creek Site

The wetland site with the smallest area is Mill Dam Creek (MDC) site, approximately 0.9 areas in size (Figure 4). The site is a long, narrow marsh running from north to south. The northern edge of the site is delineated by Mill Dam Road. The southern edge of the site consists of wooded uplands. Both the eastern and western edges of the site abut residential property. The area surrounding the site consists of wooded upland, manicured lawns, single family houses, and roadways. Culverts that run under Mill Dam Road connect the site to Mill Dam Creek, which eventually empties into Broad Bay.

3.0 RECORDS REVIEW

3.1 Physical Setting

3.1.1 Topography. The descriptions of each wetland site are presented in Section 9.2. and a topographic map of each wetland restoration site is included below. Each site is made up of salt marsh that is tidally influenced. Two sites, Great Neck South and Mill Dam Creek, have restricted tidal innundation due to roads have been constructed along the seaward edge of the site. The wetlands are connected to the Lynnhaven system by relatively small culverts that severely limit the movement of water into and out of marsh.

Figure 1: TOPOGRAPHY MAP OF THE PRINCESS ANNE WETLAND RESTORATION SITE

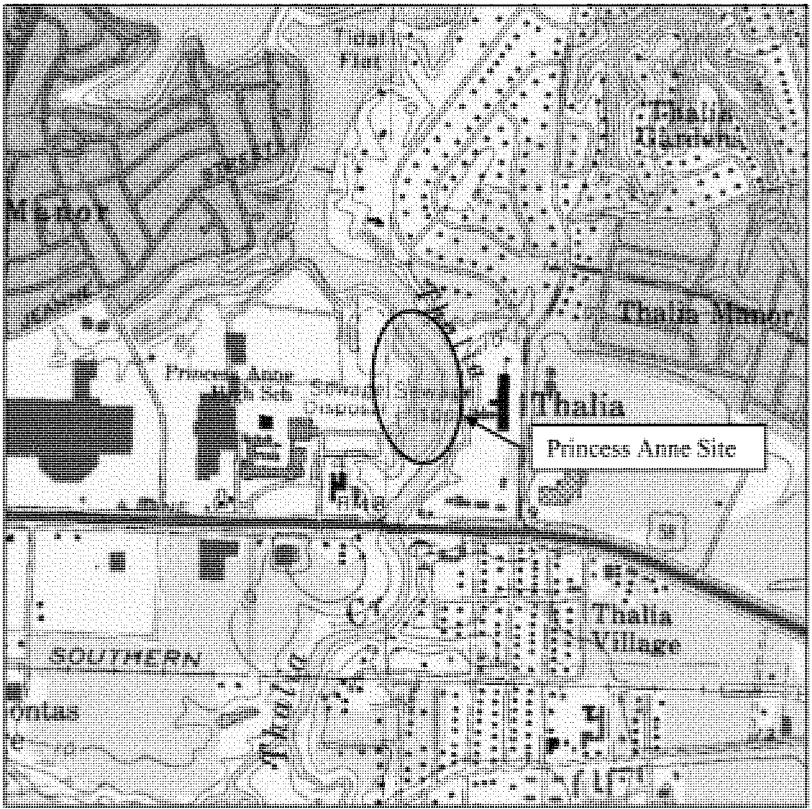


Figure 2: TOPOGRAPHY MAP OF THE GREAT NECK NORTH RESTORATION SITE AND THE GREAT NECK SOUTH DIVERSIFICATION SITE

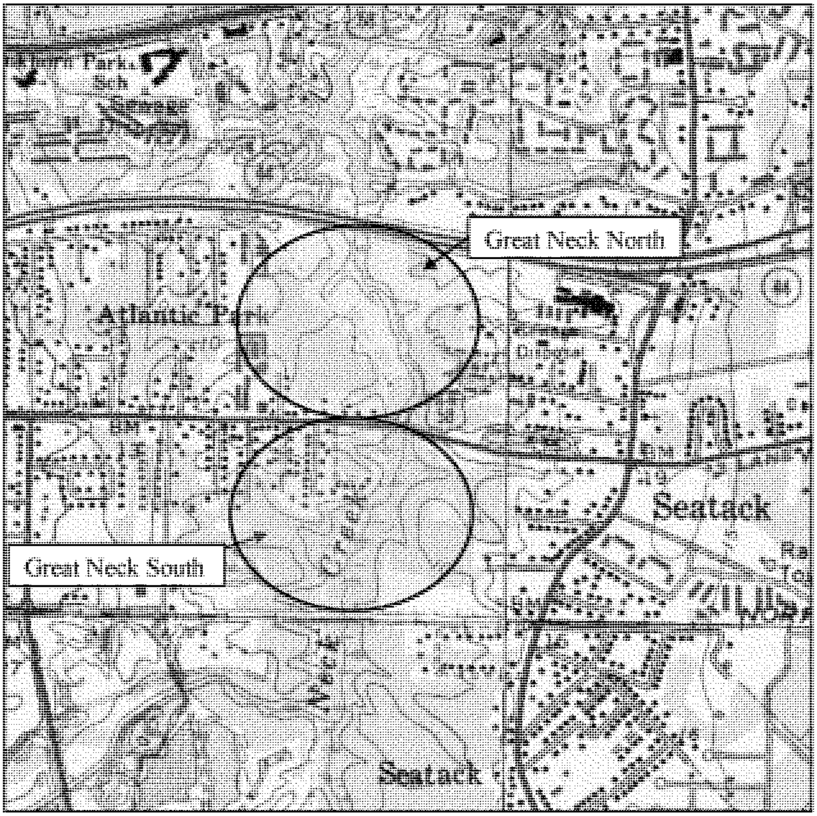
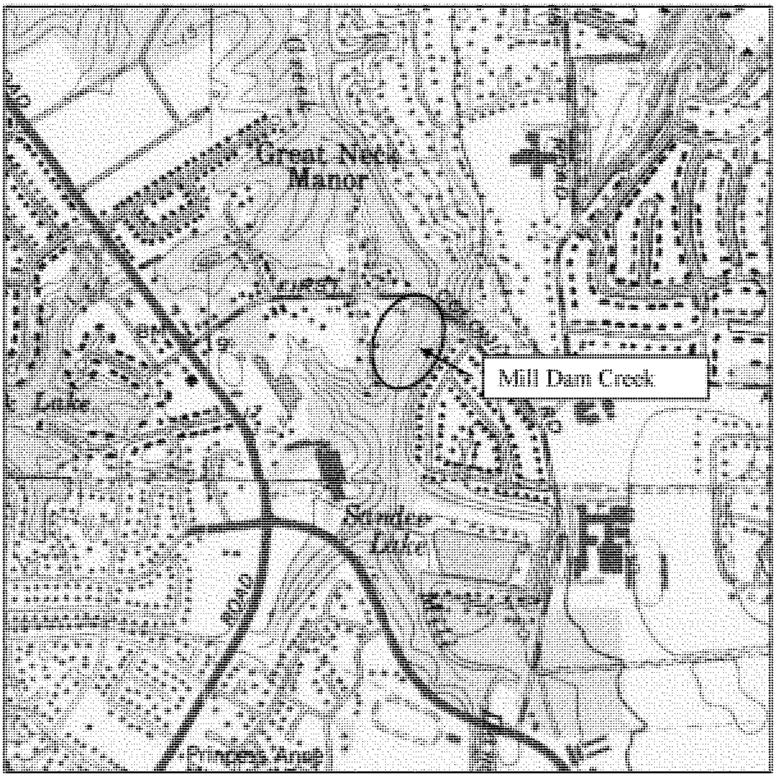


Figure 3: TOPOGRAPHY MAP OF THE MILL DAM CREEK DIVERSIFICATION SITE



3.1.2 Geology and Soils. In geologic terms, the Chesapeake Bay is very young. During the latter part of the Pleistocene epoch, which began one million years ago, the area encompassing the Chesapeake Bay was alternately exposed and submerged as massive glaciers advanced and retreated up and down North America. This movement caused sea levels to rise and fall in response to glacial expansion and contraction. The region still experiences changes in sea level, which have been observed over the past century.

The most recent retreat of the glaciers, which began approximately 10,000 years ago, marked the end of the Pleistocene epoch and resulted in the birth of the Chesapeake Bay. The melting glacial ice caused an increase in sea level that submerged the coastal regions, including the ancient Susquehanna River Valley along with many of the river's tributaries. The resulting complex of drowned stream beds now forms the Chesapeake Bay and its tidal tributaries, which includes the Lynnhaven River (USEPA, 1989).

Soils in the Lynnhaven River basin are generally characterized as loams and sandy loams, which overlie deep deposits of unconsolidated stratified lenticular sand and silt, with some gravel and clay. The Virginia Beach area contains five major soil associations, as mapped by the Natural Resources Conservation Service of the U.S. Department of Agriculture (USDA). The Newhan-Duckston-Corolla association is found in the northern coastal areas along the Chesapeake Bay. This association is characterized by very permeable soils on nearly level to steep grass and shrub covered dunes, flats, and depressions with slopes ranging from 0 to 30 percent. The soils within this association range from excessively drained to poorly drained, with a sandy substratum. The State-Tetotum-Augusta association occurs in the northern part of the city, on nearly sloping to gently sloping areas on broad ridges and side slopes. The soils in this association are characterized as well-drained to somewhat poorly drained with loamy substrates. The Acredale-Tomotley-Nimmo association occurs mainly in the southern part of the city in broad, flat areas, with slopes ranging only from 0 to 2 percent. The soils of this association are characterized as poorly drained with a loamy substrate. The Dragston-Munden-Bojac association is found on narrow ridges and side slopes in various areas of the city. The soils in this association are characterized as nearly level, well to moderately well drained, with a loamy substrate. The last found within Virginia Beach is Udorthents-Urban. These soils are characterized as being formed through activities such as excavation and filling and are often covered by impervious surfaces, such as structures or roadways. They are nearly level to steep, well to moderately well drained soils with loamy substrates (USDA, 1985; Maguire Associates, 1993).

3.2 Environmental Records

3.2.1 Brownfields. There are no records of Brownfield grants or Brownfield properties in Virginia Beach currently listed by the USEPA.

3.2.2 National Priorities List. One site in Virginia Beach is listed on the National Priorities List (NPL). The Naval Amphibious Base Little Creek facility is located on Little Creek Cove, which is north of the Lynnhaven system. Seven sources of contamination were evaluated on the facility, including the Naval Amphibious Base Landfill, Driving Range Landfill, Sewage Treatment Plant Landfill, School of Music Plating Shop Contaminated Soil and Debris, School of Music Plating Shop Neutralization Tank, Exchange Laundry Waste Disposal Area, and the PCP Dip Tank and Wash Rack Area. Wastes that have been generated and disposed at the Little Creek facility include: pesticides, paints, solvents, inorganics, heavy metals, polychlorinated biphenyls, mixed municipal wastes, nickel plating baths, chromic acid, silver cyanide, copper cyanide, lacquer stripper, perchloroethylene sludge, dyes and degreasers. Contaminates migrating from the facility have impacted or might impact fisheries and sensitive environments located down gradient from the facility. The site was proposed for the NPL on July 28 1998 and the first cleanup actions were initiated in March of 1999. Due to its location, the contamination at this facility will have little to no impact on the Lynnhaven River system.

3.2.3 Comprehensive Environmental Response Compensation Liability Information System.

A search of the Comprehensive Environmental Response Compensation Liability Information System (CERCLIS) conducted May 15th, 2012 of Virginia Beach, Virginia resulted in 8 matches (Table 2). The sites which may impact the wetland restoration sites include Mount Trashmore and the USN Oceana Naval Air Station due to the fact that both sites are upstream of the Lynnhaven Project area; however it is unlikely due to the distance between the CERCLIS list sites and the restoration sites.

3.2.4 Toxic Substances Control Act. The Toxic Substances Control Act (TSCA) provides the Environmental Protection Agency (EPA) with the authority to require reporting, record-keeping, testing requirements and restrictions related to chemical substances and/or mixtures. TSCA addresses the production, importation, use and disposal of specific chemicals including polychlorinated biphenyls, asbestos, radon and lead-based paint. There are no facilities within Virginia Beach that are monitored by the USEPA under TSCA.

3.2.5 Toxic Release Inventory. The Toxic Release Inventory (TRI) contains information on more than 650 toxic chemicals that are used, manufactured, treated, transported or released into the environment. Two results were found in a search of the area surrounding the Lynnhaven River Basin. The first release was reported by the Navy Joint Expeditionary Base at Fort Story Firing Range. 25.1 pounds (lbs) of lead were released into the environment in 2010, with and additional 28.8 lbs of lead being recycled off-site. No discharges in to streams or bodies of water were reported by this facility between the years of 1987 and 2010. The second release was reported by Virginia Beach Marble. This facility released between 2800 and 7100 lbs of styrene into the air from 2001 through 2007.

3.2.6 Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act Information (RCRAInfo), a national program management and inventory system about hazardous waste handlers, provides the public with hazardous waste information. In general, the Resource Conservation and Recovery Act (RCRA) requires that all generators, transporters, treaters, storers, and disposers of hazardous waste provide information about their activities to state environmental agencies. These agencies, in turn, pass on the information to regional and national EPA offices. 555 RCRA permitted facilities located in Virginia Beach. There are a smaller number of facilities immediately adjacent to each of the wetland sites. There are three facilities immediately adjacent to the Great Neck South site, four adjacent to the Great Neck North site, 14 near the Princess Anne site and seven near the Mill Dam Creek Site (Table 1).

Table 1: SITES LISTED BY RCRAINFO THAT ARE IMMEDIATELY ADJACENT TO THE WETLAND RESTORATION SITES.

Wetland Site Name	RCRA Facility	Generator Type
Great Neck South	FAST FARE INC T/A CROWN VA-529	Small Generator
	LEE PAPPAS BODY SHOP	Conditionally Exempt Small Generator
	SEA ATTACK AUTO AND TIRE CENTER	Conditionally Exempt Small Generator
Great Neck North	AMOCO #60086-TANKS	Small Generator
	FAST FARE INC T/A CROWN VA-529	Small Generator
	LEE PAPPAS BODY SHOP	Conditionally Exempt Small Generator
	SEA ATTACK AUTO AND TIRE CENTER	Conditionally Exempt Small Generator
Princess Anne	ALBANO CLEANERS INC	
	DOMINION CHRYSLER PLYMOUTH INC	Small Generator
	EXXON CO USA #26015	Conditionally Exempt Small Generator
	EXXON CO USA 27294	Conditionally Exempt Small Generator
	FOTEK CORP T/A THE FILM FACTORY	Small Generator
	KMART #3801	Small Generator
	PEARLE EXPRESS	Conditionally Exempt Small Generator
	PRINCESS ANNE HIGH	Conditionally Exempt Small Generator, Transporter
	SEARS ROEBUCK & CO	Conditionally Exempt Small Generator
	SHELL OIL CO	Small Generator
	SHERWIN-WILLIAMS CO THE	No Designation Given
	PEMBROKE W SHOPS	No Designation Given
	TIRE KINGDOM INC. # 416	Conditionally Exempt Small Generator
	VIRGINIA INHALATION THERPY SV	No Designation Given
Mill Dam Creek	AMOCO #60180-TANKS	Small Generator
	ENGINUITY	Small Generator
	EXXON CO U S A RA527766	Small Generator
	EXXON CO USA #27766	Small Generator
	FIRST COLONIAL HIGH	Conditionally Exempt Small Generator, Transporter
	STAR ENTERPRISE	No Designation Given
	TEXACO STATION-TANKS	Small Generator

3.2.7 Resource Compensation Recovery Act Corrective Action Facilities. The EPA website lists two facilities in Virginia Beach as a RCRA corrective action facility. The first is Controls Corporation of America (CONCOA). The EPA issued its Final Decision regarding the facility on June 16, 2009 stating that Corrective Action was "Completed without Controls". The second is the Naval Air Station Oceana. The site was first listed in August 30, 1988 and was not identified for corrective action.

<u>3.2.8 Hazardous Waste Report (Biennial Report).</u> The Hazardous Waste Report (Biennial Report) contains data on the generation, management, and minimization of hazardous waste from large quantity generators and data on waste management practices from treatment, storage, and disposal facilities. Data about hazardous waste activities is reported for odd number years (beginning with 1989) to EPA. In 2009, the most recent data available, there are four facilities in Virginia Beach which required to provided data to the Biennial Report. None of the sites are adjacent to the four wetland sites.

<u>3.2.9 State Superfund.</u> Three sites located in Virginia Beach are state listed Superfund sites. This includes the Oceana Naval Air Station, the Naval Amphibious Base, and Oceana Salvage. The Oceana Naval Air Station contains an open pit where 110,000 gallons of waste oil and fuels were disposed between the mid-1950's and the early 1960's. The site also contains a building where waste solvents and oils were poured into a waste oil tank for disposal and soil around the tank was contaminated. Hazardous substances of concern that were detected at the site include hydraulic fluid, chlorinated and aromatic hydrocarbons, jet fuel, solvents, asbestos, waste oil, PCBs, pesticides, VOCs, agitine and free phase diesel fuel. The Little Creek Naval Amphibious Base is included on the National Priorities List and is described in a previous section of this document. Investigation of the Oceana Salvage property in 1997 found surface soils contaminated with lead, PDBs, PAHs and petroleum products.

<u>3.2.10 Permit Compliance System and Integrated Compliance Information System.</u> PCS/ICIS lists 14 facilities that currently hold National Pollutant Discharge Elimination System (NPDES) permits water discharge permits issued within Virginia Beach. Three of which are considered major dischargers. Five facilities are located in the area surrounding the Lynnhaven River Basin. The facilities which have been issued the permits are the Air Nation Guard, Coastal Walk Condominiums, HRSD Chesapeake-Elizabeth Waste Water Treatment Plant, US Navy Air Station Oceana Base and the US Navy Little Creek Amphibious Base.

4.0 FINDINGS AND OPINIONS

4.1 Contaminant release mechanisms

The only project measure which may result in negative environmental impacts due to HRTW is the restoration of the wetland sites. The construction of the reef habitat, planting of submerged aquatic vegetation, and stocking of bay scallops are not be expected to result in the generation and/or disturbance of hazardous materials or solid waste. Habitat restoration of the wetland sites will involve the physical alteration of four sites.

Of the four wetlands restoration sites, Princess Anne and Great Neck North, will involve the excavation and removal of approximately 2 to 4 ft of the upper peat layer. The material will be excavated in order to remove as much invasive vegetation, including rhizomes, roots and foliage, as possible to prevent recolonization. The site will then be grated to the elevation optimal for the growth of *Spartina alterniflora,* a native salt marsh grass that inhabits the lower marsh. Materials generated from sediment excavation activities at the wetland restoration sites will be evaluated as a solid waste in accordance with HTRW guidance as appropriate prior to disposal at a landfill facility.

The ecological function will be improved at the diversification sites, Great Neck South and Mill Dam Creek, through the habitat "diversification." Habitat features, including islands, channels, and pools, will be constructed to break up the homogeneous *P. australis* stands. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material. The material excavated from the tidal creeks and pools will be used to build upland mounds that will be planted with native shrubs or grasses.

4.2 Exposure Routes

If contaminants are present in the sediment of the salt marsh sites, routes of exposure for those contaminates would include direct contact with the contaminated soils, contact with dissolved contaminants if soil is released into the water column or through breathing in contaminates evaporating into the air once the compounds are exposed.

4.3 Potentially Exposed Populations

The populations that could be at risk of exposed would depend on the route the material is released into the environment. The population at risk of direct exposure would include the workers who are doing the restoration work and members of the general public who are using the wetland sites while construction is taking place. People living adjacent to the site and construction workers on-site would be at risk of inhalation of airborne contaminants. Members of the public who come in direct contact with water of the Lynnhaven River system would be exposed to chemicals released into the water column. In addition, flora and fauna in the Lynnhaven River system would be exposed to the dissolved contaminants. Once incorporated into the organisms in the system, fishermen and other people who ingest those organisms would be exposed to the contaminants.

4.4 Contamination from Surrounding Properties

The investigation into the existing records of the area surrounding the proposed project sites revealed a low probability that the areas contain a recognized environmental condition due to contamination of the surrounding area. The predominant land use surrounding the Lynnhaven River Basin is suburban residential, with a limited amount of commercial development located in the area. There is a single site, the Naval Amphibious Base Little Creek, in Virginia Beach which is included on the National Priorities List of the Superfund Program; however this site is not located within the project area. At the writing of this report, there is no know hazardous, toxic, or radioactive waste (HTRW) issues that occur within the boundaries of the project area which would halt the feasibility phase of this project.

Table 2: THE RESULTS OF A SEARCH OF THE COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION LIABILIT INFORMATION SYSTEM (CERCLIS) CONDUCTED MAY 15TH, 2012 FOR VIRGINIA BEACH, VIRGINIA

Search Criteria:
County: *VIRGINIA BEACH*
State(s): *Virginia*

Found **8** site(s) that match above search criteria:

EPA ID	Site Name	City	Non-NPL Status Code	Non-NPL Status Date	NPL Status Code
VA6210020875	FORT STORY	VIRGINIA BEACH	Other Cleanup Activity: Federal Facility-Lead Cleanup	9/27/2004	N
VAD981739238	LYNN HAVEN BAY SITE	LYNN HAVEN SHORES	NFRAP-Site does not qualify for the NPL based on existing information	10/22/1992	N
VAD988196739	MT. TRASHMORE	VIRGINIA BEACH	Other Cleanup Activity: State-Lead Cleanup	4/10/2002	N
VA5170022482	NAVAL AMPHIBIOUS BASE LITTLE CREEK	VIRGINIA BEACH	[Blank Code]	[Blank Date]	F
VAN000306180	OCEANA SALVAGE	VIRGINIA BEACH	Removal Only Site (No Site Assessment Work Needed)	1/30/2006	N
VA1170090012	USN CAMP PENDLETON	VIRGINIA BEACH	Other Cleanup Activity: Federal Facility-Lead Cleanup	9/27/2004	N
VA5170022938	USN FLEET COMBAT TRAINING CENTER	VIRGINIA BEACH	Other Cleanup Activity: Federal Facility-Lead Cleanup	9/27/2004	N
VA2170024606	USN NAVAL AIR STN OCEANA	VIRGINIA BEACH	Fed Fac Preliminary Assessment Review Start Needed	10/4/2000	N

APPENDIX D

CULTURAL RESOURCES

CULTURAL RESOURCES

The following description of Native American culture in the Virginia Beach area is taken from the following report " *Phase I Archaeological Survey of Twelve Acres and Phase II Archaeological Significance Evaluation of 44VB240, 44VB241, and 44VB242 at the Great Neck Point Disposal Area, City of Virginia Beach"* (McDonald and Laird, 1996).

The earliest inhabitants of southeastern Virginia were Native Americans, who were present in the area before 8000 B.C. The oldest cultural remains found in the area are from the Paleo-Indian period, which is the time period before 8000 B.C. The most common site of this type found in Virginia is the isolated projectile point, and in southeastern Virginia these sites are most commonly found in locations associated with the Dismal Swamp and its western border. However, several of these sites have been found in the Lynnhaven watershed, specifically in the Great Neck area, at First Landing State Park, and at the former Bayville Farm property.

Archaeological sites from the Archaic time period, which extends from approximately 8000-1200 B.C., are more common than those from the Paleo-Indian period. By this time, the Indians were making use of a greater variety of plants and habitats. The population density increased across Virginia, including the Coastal Plain. Within southeastern Virginia the large base camps that existed on the edges of the Dismal Swamp were being abandoned seasonally as the large groups split into smaller camps and moved into estuarine areas. Typical sites of this era that have been found in Virginia Beach include various camp sites and quarry sites for extracting quartz and quartzite.

The vast majority of the prehistoric sites in the Lynnhaven area date to the Woodland period (1200 B.C.-1607). This period is characterized by a more sedentary lifestyle increasingly dependent on agriculture and a more complex social organization. There is more focus on riverine and estuarine settings and subsistence resources and an increase in material culture, especially ceramics. Several significant sites found in the watershed that date to the Early and Middle Woodland period are estuarine-oriented base camps that were occupied most of the year. These sites contained ceramics and shellfish remains, and one site contained human remains. By the Late Woodland period, Native Americans were cultivating maize in addition to the major use of marine and river resources. Other food items being consumed were native berries, nuts, fish, shellfish, birds, bird eggs, deer, and small mammals. By 1500, Native Americans in this region had established permanent villages for agriculture.

By 1600, the Indian society in the Coastal Plain had evolved into a chiefdom society with Powhatan as the top chief of about 31 tribes. During the 1500s, the area occupied today by the cities of Norfolk, Virginia Beach, Chesapeake, and Portsmouth was occupied by the Chesapeake Indian tribe. Maps of the late 1500s show possible Chesapeake Indian villages in the Virginia Beach region. The village named “Apasus” appears on the western side of the Western Branch of the Lynnhaven River on a 1590 map attributed to Theodor de Bry (McSherry, 1993). By the time the English colonists arrived in 1607, the Chesapeake tribe in southeastern Virginia had been eliminated by Powhatan and the area resettled by the Nansemonds, who were also a part of the Powhatan confederacy (McDonald et al., 1996). John Smith’s early explorations in the Virginia Beach area in 1608 did not result in his encountering any Indian settlements. (Frazier Asso.,) In 1609, English colonists went 6 to 7 miles up the Lynnhaven or Elizabeth River and found a few Indian houses but no inhabitants (McDonald and Laird, 1996).

Virginia Beach’s recorded history generally begins in 1607 with the landing at Cape Henry by the English settlers who eventually established the first permanent colony at Jamestown. Although the first colonists settled inland away from the coast, by 1635 settlers had started to move into the Hampton Roads area, settling along the Elizabeth, Lynnhaven, and North Landing Rivers and the north-south ridges of arable land (Frazier Asso., 1992). The initial settlement of the Lynnhaven took place along the branches and coves of the river since the water was the main source of transportation, trade, and communication. Many of the early land patents noted the sites of former Indian settlement on the patent, and these early colonial settlements tended to be in areas that had been previously cleared by the Indians (McDonald and Laird, 1996).

One of the earliest settlements in the area took place on the 5,350 acres of land Adam Thoroughgood owned at the mouth of the Western Branch of the Lynnhaven River. An Episcopal Church was established here in 1640, and the settlement became a small commercial center for the surrounding countryside throughout the century. Thoroughgood was instrumental in establishing the boundaries for this Episcopal parish, and these boundaries later became the boundaries for Princess Anne County, which would ultimately make up most of the city of Virginia Beach. The first county courthouse was built in this area along the river at the site of a ferry landing. In 1691, it became the county seat for Princess Anne County and the business and social center of the county. When the courthouse was relocated in 1751 to the Newtown community, which is located southwest of the Lynnhaven area, the Lynnhaven community lost much of the activity associated with being the county seat (Frazier Asso., 1992).

In general, Princess Anne County, which had been agricultural from its origins, remained primarily agricultural through the 18^{th} and 19^{th} centuries. By 1750, agriculture had become more diversified in response to the soil depletion from extensive tobacco farming. The farming of grains, especially corn, became more prevalent. After the Revolutionary War, the county's population declined for several decades as residents began migrating west to the Piedmont areas of Virginia and North Carolina in search of more economic and social opportunities (McDonald et al., 1996). Those farmers who remained tended to be small planters or tenant farmers rather than plantation owners although there were still some such as Thomas Walke III, who built Upper Wolfsnare on the Lynnhaven River in 1759 and owned 7,000 acres. By the mid-1800s farmers began to truck farm, and logging of pine and cypress was taking place (Goode and Dutton, 1999).

Neither the Revolutionary or Civil Wars affected Princess Anne County the way they did other parts of the state that were the sites of major battles. Lord Dunmore came through the county just before the Revolutionary War to collect arms, ammunition, and supplies, but no other significant action took place during the war itself. During the Civil War, the Federal army took control of the county in 1862 and maintained without major incident throughout the war (Goode and Dutton).

The original town of Virginia Beach began as a small settlement near the Seatack Life Station, which is located near the Oceanfront. Toward the end of the 19^{th} century, the town began to grow quickly as hotels and vacation cottages were constructed. By 1906, Virginia

Beach had become an incorporated town, and in 1923, it annexed a small part of the county. In 1963, Princess Anne County and the town of Virginia Beach merged to become the city of Virginia Beach with its current boundaries (Frazier Asso., 1992).

The following table lists the historical resource sites that have been recorded in the vicinity of the potential restoration sites. This table includes cultural resource sites near two restoration sites that were not included in the tentatively selected plan (Narrows to Rainey Gut and Fish House Island).

CULTURAL RESOURCES SITES NEAR POTENTIAL RESTORATION SITES

Potential Restoration Site	VDHR Site #	Description	NHRP Recommendation	Distance to Restoration Site(ft.)(approx.)
Milldam Creek	134-0049	18th c. house	None	2,300
Milldam Creek	44VB0059	18th c. dwelling, site totally destroyed	None	2,300
Milldam Creek	44VB0102	19th c., map projection	None	2,500
Narrows to Rainey Gut	134-0099	Seashore State Park Historic District	Listed	adjacent
Narrows to Rainey Gut	44VB0040	Woodland camp	None	265
Narrows to Rainey Gut	44VB0041	Woodland shells, prehistoric pottery	None	525
Narrows to Rainey Gut	44VB0096	19th c., map projection	None	2,285
Narrows to Rainey Gut	44VB0100	19th c., map projection	None	880
Narrows to Rainey Gut	44VB0359	Mixed prehistoric (lithic scatter) & 19th-20th c. pieces of glassware, ceramics, brick:site heavily destroyed	None	950
North Great Neck	134-0123	1936 house	Not eligible	2,500
North Great Neck	134-0124	1935 house	None	2,000
North Great Neck	134-0132	house, no date given	None	1,100
North Great Neck	134-0135	house, no date given	None	1,100
North Great Neck	134-0137	1930 house	None	2,400
North Great Neck	134-0138	1900 house	None	1,300
North Great Neck	134-0164	1900 house	None	650
North Great Neck	134-0165	1900 house	None	1,100
North Great Neck	134-0567	1920 church	None	1,365
North Great Neck	134-0941	1940 house	Not eligible	2,500
North Great Neck	134-0943	1940 house	Not eligible	1,800
North Great Neck	134-5017	1940 house	None	2,200
North Great Neck	134-5020	1940 house	None	1,800
North Great Neck	134-5058	1943 house	Not eligible	1,300

North Great Neck	134-5059	1935 house	Not eligible	2,000
North Great Neck	134-5060	1945 house	Not eligible	2,100
North Great Neck	134-5061	1940 house	Not eligible	1,600
North Great Neck	134-5062	1945 house	Not eligible	1,600
North Great Neck	134-5064	1940 house	Not eligible	1,800
North Great Neck	134-5065	1950 house	Not eligible	1,500
North Great Neck	134-5067	1945 house	Not eligible	1,100
North Great Neck	134-5068	1950 house	Not eligible	1,600
North Great Neck	134-5069	1950 house	Not eligible	1,700
North Great Neck	134-5071	1945 house	Not eligible	1,900
North Great Neck	134-5072	1940 house	Not eligible	1,700
North Great Neck	134-5073	1940 house	Not eligible	1,700
North Great Neck	134-5076	1945 house	Not eligible	1945
North Great Neck	134-5077	1950 house	Not eligible	1,300
North Great Neck	134-5078	1940 house	Not eligible	1,600
North Great Neck	134-5145	Norfolk and Virginia Beach Railroad	Eligible	1,600
Princess Anne H. S.	134-0605	1930 Tidewater Tuberculosis Hospital	None	800
Princess Anne H. S.	134-5145	Norfolk and Virginia Beach Railroad	Eligible	1,900
South Great Neck	134-0124	1935 house	None	1,300
South Great Neck	134-0135	house, no date given	None	2,300
South Great Neck	134-0138	1900 house	None	600
South Great Neck	134-0140	house, no date given	None	1,400
South Great Neck	134-0163	1900 house	None	625
South Great Neck	134-0164	1900 house	None	600
South Great Neck	134-0165	1900 house	None	600
South Great Neck	134-0567	1920 church	None	1,700
South Great Neck	134-0937	1940 house	Not eligible	1,600
South Great Neck	134-0938	1920 house	Not eligible	1,500
South Great Neck	134-0939	1940 house	Not eligible	1,300
South Great Neck	134-0940	1940 house	Not eligible	1,400
South Great Neck	134-0941	1940 house	Not eligible	900
South Great Neck	134-0943	1940 house	Not eligible	700
South Great Neck	134-5015	1930 house	None	500
South Great Neck	134-5016	1930 house	None	500

South Great Neck	134-5017	1940 house	None	1,700
South Great Neck	134-5018	1940 house	None	1,600
South Great Neck	134-5019	1940 house	None	700
South Great Neck	134-5020	1940 house	None	1,700
South Great Neck	134-5059	1935 house	Not eligible	1,500
South Great Neck	134-5060	1945 house	Not eligible	1,100
South Great Neck	134-5061	1945 house	Not eligible	1,100
South Great Neck	134-5062	1940 house	Not eligible	1,200
South Great Neck	134-5063	1945 house	Not eligible	1,200
South Great Neck	134-5064	1950 house	Not eligible	1,200
South Great Neck	134-5065	1950 house	Not eligible	900
South Great Neck	134-5067	1945 house	Not eligible	700
South Great Neck	134-5068	1950 house	Not eligible	1,500
South Great Neck	134-5069	1950 house	Not eligible	1,500
South Great Neck	134-5071	1945 house	Not eligible	1,600
South Great Neck	134-5072	1940 house	Not eligible	1,700
South Great Neck	134-5073	1940 house	Not eligible	1,900
South Great Neck	134-5076	1945 house	Not eligible	1,600
South Great Neck	134-5145	Norfolk and Virginia Beach Railroad	Eligible	adjacent
Fish House Island	134-5167	1927 restaurant	Not eligible	350
Fish House Island	134-5168	1945 house	Not eligible	1,300
Fish House Island	134-5171	1958 bridge	Not eligible	650
EFH 1	44VB0077	Woodland site with bifaces, points, flakes, pottery	Eligible	600
EFH 2	44VB0080	Woodland ceramics, flakes, and bifaces	None	2,500
EFH 4	134-0081	1920 house	None	500

Source: Virginia Department of Historic Resources

APPENDIX E

REAL ESTATE PLAN

Lynnhaven River Basin Ecosystem Restoration Project, Virginia Beach, Virginia

UNITED STATES ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT
LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION STUDY
REAL ESTATE PLAN

TABLE OF CONTENTS

EXHIBITS

NORFOLK DISTRICT, CORPS OF ENGINEERS, LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION STUDY REAL ESTATE PLAN

1.0 AUTHORIZATION

The Lynnhaven River Basin Ecosystem Restoration Study ("Project") is authorized by Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted May 6, 1998. The authorization states:

> *Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives that the Secretary of the Army is requested to review the report of the Chief of Engineers on the Lynnhaven Inlet, Bay and connecting waters, Virginia, published as House Document 580, 80th Congress, 2nd Session, and other pertinent reports, to determine whether any modifications of the recommendations contained therein are advisable at the present time in the interest of environmental restoration and protection and other related water resources purposes for the Lynnhaven River Basin, Virginia.*

2.0 PURPOSE

This Real Estate Plan is for planning purposes and supports the Lynnhaven River Basin Ecosystem Restoration Study for the Lynnhaven River in Virginia Beach, Virginia. The figures in this report are subject to changes as the project is refined during the next phase of Pre-Construction Engineering and Design.

3.0 LOCATION

The study area is located wholly within the boundaries of the City of Virginia Beach, Virginia. The City of Virginia Beach is located in Southeastern Virginia, approximately 100 miles from the state capital in Richmond, Virginia. The Lynnhaven River Basin is a 64-square mile tidal estuary in the lower Chesapeake Bay Watershed.

4.0 BACKGROUND AND PROJECT DESCRIPTION

The Restoration Measures of the Tentatively Selected Recommended Plan are made up of four types of restorations. They are: (1) Sub-aquatic Vegetation (SAV) Restoration, (2) Bay Scallop Restoration, (3) Reef Habitat Creation, and (4) Wetlands Restoration. The general locations of these restoration sites are shown in Exhibit "A." The SAV, Bay Scallop Restoration, and Reef Habitat Projects will be constructed on river bottoms owned and managed by the Commonwealth of Virginia ("Commonwealth"). The Non-Federal Sponsor (NFS) for this Project is the City of Virginia Beach, Virginia. The NFS will obtain any required permits, including a permit for work on state-owned river bottoms from the Virginia Marine Resources Commission (the "Commission" or "VMRC"). The Norfolk District Project Manager (PM) for this Project has confirmed that the VMRC permit is appropriate and will apply to the Project activities. Some of the identified parcels for SAV, scallop, and reef habitat are currently leased by the Commonwealth of Virginia for the purposes of oyster harvesting.

Description of the Project

Submerged Aquatic Vegetation (SAV). Sites will be located in Broad Bay (approximately 44.3 acres) and the Lynnhaven Mainstem (approximately 41.3 acres). The sites will be planted with SAV seeds from small boats. Seeds may also be planted using divers or mechanical planters operated from a small boat. Monitoring will be done to determine the full extent of the SAV beds. The SAV will also be adaptively managed and re-seeded if necessary.

Reintroduction of Bay Scallops. The sites selected for reintroduction of the bay scallop are located within the SAV restoration sites (approximately 22 acres). The SAV beds would be restored first, as bay scallops are known to prefer it to other substrates. Two main techniques are used in restoring bay scallops, direct stocking and cages on the river bottom.

Reef Habitat. The proposed sites will be located in the Lynnhaven Mainstem and the Broad Bay/Linkhorn complex. The sites in the Lynnhaven total approximately 8.345 acres. The sites in the Broad Bay/Linkhorn complex total approximately 15.99 acres. One site in Broad Bay has some soft bottom that would first require the placement of rock filled mats on the bottom with the reef balls being placed on top to prevent subsidence. This site is approximately ten acres in size.

Wetland Restoration/Diversification. Four sites within the Lynnhaven River Basin have been identified for restoration or diversification of wetlands in the Lynnhaven Restoration Project. Two sites, the Princess Anne (3.82 acres) and the Great Neck North Sites (19.89), are selected for restoration of the indigenous salt marsh community and reduction of the population of invasive plant species. Habitat restoration will involve both physical alteration of the site and herbicide application. Features, such as shallow pools, upland islands, and channels will be created to increase the diversity of the marsh habitat and to allow seawater to flood the area.

Ecological function at two other sites, Mill Dam Creek (0.95 acres) and Great Neck South (13.71 acres) sites, will be established by increasing habitat diversity. Ecological function will be increased through the construction of habitat features, including islands, channels, and pools. Small drainage dikes will be widened into creeks to extend the range of tidal inundation. Shallow, open pools or "scraps" will be created by excavating the top layer of material.

There are a total of 41 river bottom sites and 28 wetlands sites for a total of 69 sites needed for this project. The local sponsor will acquire the sites through donation, negotiation, and, as a last resort, condemnation.

Operations and Maintenance

Operations and maintenance (O&M) requirements for the wetland sites include annual inspections of the areas for a period of fifty years to ensure native plant growth and no encroachment of invasive plant species. The inspection would determine if additional sprig plants or the application of herbicides is necessary to restore the required wetland function. An assessment of the rock structures for displacement from wave action and/or settlement due to long term consolidation of the subgrade should also be included in the inspection. Annual inspections of the areas restored with Sub-aquatic Vegetation (SAV) Restoration, Reef Habitat Restoration, and Bay Scallop Restoration are also required for a period of fifty years.

After the initial 10 year's the USACE will close out the project and all monitoring (including the fish reefs, wetlands, SAV and scallops) will be the responsibility of the NFS, Virginia Beach. Protective measures may also be required of the NFS in conjunction with the U.S. Coast Guard (USCG) and the Commonwealth. Such adaptive management actions could include signage requiring "no wake" zones over restored SAV beds to reduce prop damage within the bed, or possibly marking the SAV beds "off limits" to boat traffic, at least those located in shallow (> 3ft MLW) waters. This will be considered if prop damage to established SAV beds is observed. Enforcement of these measures will be the responsibility of the NFS, the USCG, and/or the state.

5.0 PROJECT LANDS, EASEMENTS, RIGHTS-OF-WAY, RELOCATIONS AND DISPOSAL AREAS (LERRD)

5.01 Sub-aquatic Vegetation (SAV) Restoration and Bay Scallop Restoration Projects and, Reef Habitat

a. These components will be constructed on state-owned river bottoms. The NFS, in coordination with NAO Planning and Policy, will obtain any necessary environmental or construction permits, including, if needed, a VMRC permit.

b. The standard estate required for environmental restoration projects is fee. Pursuant to section 28.2-1200.1 of the VA Code, the Commonwealth shall not convey fee simple title to state-owned bottomlands covered by waters, but the Commonwealth may grant a lease, easement, or other limited interest in state-owned bottomlands covered by waters as long as the property is used by a governmental entity for the performance of a governmental activity. Thus, the standard estate, fee, required by regulation for environmental restoration projects, is not available for the SAV, reef habitat and scallop restoration. The NFS will acquire from the Commonwealth of Virginia a non-standard perpetual easement over the river bottom required for the project. Exhibit D is a map that shows the location of the proposed sites for the SAV, reef habitat and scallop restorations. There are a total of approximately 109.968 acres comprised of 41 different parcels. These 41 parcels are currently leased by third parties. Exhibit E is a list of the 41 parcels, showing the acreage of each parcel, for a total of 109.968 acres. The NFS will acquire these parcels and will obtain four easements in perpetuity from the Commonwealth for river bottom parcels that are a part of the Project.

c. The proposed sites for SAV, scallop and reef habitat are currently leased for oyster harvesting. The NFS will acquire or terminate these leases by donation, negotiation or, as a last resort, condemnation.

d. No Temporary Work Area Easements are anticipated to be required for these activities as all construction and access will take place from work boats in public access waterways.

5.02 Wetlands Restoration Project

a. The Wetlands Restoration will be constructed on 38.4 acres of land owned by the NFS and by private property owners. Exhibit B shows the 28 sites that are proposed for the Wetlands Restoration and whether the site is owned by the NFS or by private owners. For sites owned by private parties, the NFS will acquire by donation, negotiation/purchase or condemnation. The NFS, in coordination with the Norfolk District Planning and Policy Section, will obtain any necessary environmental and construction permits.

b. The standard estate required for environmental restoration projects is fee. However, it is proposed that the NFS will obtain a non-standard wetlands easement in perpetuity over the wetlands restoration sites identified in Exhibit B for the Wetlands Restoration Project in order to provide perpetual protection of the Project on the property as shown on the map at Exhibit C. This non-standard estate is recommended because it will grant the same protection that could be obtained for the project through a fee estate; namely, protection in perpetuity for the functions and values of the Project. The use of a non-standard wetlands easement would provide required protection while allowing the property owners to continue ownership and use of the property for activities that would have no impact on the Project. Acquisition of a fee simple interest would add no significant value to the Project, would add more acquisition expense to the Project, would eliminate the value of having owners provide long-term stewardship of the Project, may create unnecessary obligations or added expenses for the NFS, may create a burden and detriment to the current owners, and may create a disincentive to owners to participate in the Project. In sum, there is no appreciable gain to the Project from a fee interest as opposed to a non-standard wetlands easement in perpetuity, yet there are numerous detriments. A non-standard wetlands easement can be development to protect every element, function and value that is needed for the Project. The gross appraisal indicates that the use of the wetland easement estate would allow the sites to continue to support the parent tract as open space and for passive recreational activities. The Project cost for fee is estimated to be approximately four times the easement values. The appraiser justified the use of the 25% as follows:

"Impact to the underlying fee land is minimal as the proposed subject easement areas are in the flood hazard zone and CBPA areas. A weight of 25% is therefore applied on the unit of estimated wetland fee value of $6,700 per acre for an indication of subject perpetual easement value of $1,675 per acre (25% of $6,700/acre)."

The Estate used for the appraisal is as follows:

WETLAND EASEMENT: A perpetual and assignable right and easement to construct, operate, and maintain wetland restoration improvement works on, over and across (the land described in Schedule A) (Tracts Nos. , and) for the purposes as authorized by the Act of

Congress approved, including the right to clear, cut, fell, remove, excavate, and dispose of any and all timber, trees, underbrush, buildings, improvements and/or other obstructions there from; plant phragmites, eradication of phragmites; place stone riprap and/or low sill breakwaters to excavate, dig, anchor, dredge, cut away, and remove any or all of said land and to place thereon dredged material, ''Bay'' and/or ''Goliath'' and/or ''Ultra'' reef balls, right of ingress/egress for annual inspections and for such other purposes as may be required in connection with said work of improvement; reserving, however, to the owners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

c. Temporary Work Area Easements, using the standard estate, will be obtained for construction, laydown and staging of construction materials and equipment needed to develop the wetland areas, and for access during construction. These interests will be acquired by donation, negotiation, or condemnation.

Project acreages and Estates

Project Activity	Acreage – approximate	Real Estate LERRD
SAV	Lynnhaven Mainstem and Broad Bay (85.6)	Easements in perpetuity (State-owned river bottoms)
Bay Scallops	Included with SAV sites (22)	Easements in perpetuity (State-owned river bottoms)
Reef Habitat	Lynnhaven Mainstem and Broad Bay (24.3)	Easements in perpetuity (State-owned river bottoms)
Wetlands Restoration	Princess Dam (3.82) Great Neck North (19.9) Mill Dam Creek (0.95) Great Neck South (13.7)	Wetlands Easements in perpetuity; Temporary Work Area Easements

Note: The 22 acres of Bay Scallops are being placed within the SAV sites and are included the 109.9 acres of SAV and Reef Habitat easement acreage (85.6 +24.3). The total Wetlands acreage is rounded to 38.4 acres.

5.03 Non-Standard Estates Proposed For This Project

a. **Easements for SAV, Scallops and Reef Habitat**. Easements in perpetuity will be obtained by the NFS to protect the SAV, scallops and reef habitat restoration. Approval of the form of these easements will be sought later after locations and acreages are finalized in the design phase. This non-standard estate, an easement in perpetuity, will be sufficient to meet the needs of the Project in that the easements will provide all necessary measures and restrictions to protect and preserve the Project in perpetuity. The purpose of the easements is to preserve and protect the ecologic and conservation values of the Project by imposing restrictions and providing for enforcement. The conservation values of the Project are to restore the functions and values of SAV, scallops and reef habitat.

b. **Wetlands Easement**. The wetlands easement in perpetuity needed for the Wetlands Restoration Project will be obtained by the NFS to protect the Wetlands Restoration. Approval of the form of this wetlands easement will be sought later after locations and acreages are finalized in the design phase. This non-standard estate, a wetlands easement in perpetuity, will be sufficient to meet the needs of the Project in that it will provide all necessary measures and restrictions to protect and preserve the Project in perpetuity. The purpose of the wetlands easement is to preserve and protect the conservation values of the Project in perpetuity by imposing restrictions on the use of the Property and providing for enforcement. The conservation values of the Project are to restore the functions and values of the wetlands. A request for approval of the non-standard estate is to be submitted to HQUSACE for review and approval in June 2013.

5.04 Standard Estates to Be Used For This Project

Access and Temporary Work Area Easements

Location. Locations of Temporary Work Area Easements will be determined during the design phase of the Project. These easements will also provide needed access and is temporary to cover the period of construction. Access is not needed after the Wetlands Restoration is constructed because the wetlands easement will allow for required access.

Temporary Work Area Easement: Temporary easement and right-of-way in, on, over and across (the land described in Schedule A) for a period not to exceed three years, beginning with date possession of the land is granted to the United States, for use by the United States, its representatives, agents, and contractors as a work area, including the right of access and the right to move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the Lynnhaven River Basin Ecosystem Restoration Project, together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

6.0 MAPPING

Mapping is included in Exhibits A, C, and D. Exhibit A is a Project Map of the proposed Lynnhaven River Ecosystem Restoration Sites, Virginia Beach, VA. Exhibit C is a map of the proposed Wetland Restoration Sites, Virginia Beach, VA. Exhibit D is a map showing the proposed sites for the SAV/Scallop Restorations and Reef Habitat. During the next phase of the Project, maps will be updated if necessary if any changes were made to the proposed sites.

7.0 FEDERAL AND NON-FEDERAL SPONSOR PROJECT LAND OWNERSHIPS

7.1 FEDERALLY OWNED LAND and FEDERAL PROJECTS

There are no federally owned lands within the Project area. There are three federally authorized projects in the Lynnhaven watershed, the Lynnhaven Inlet project, Virginia Beach Canal No. 2, and the Lynnhaven Oyster Restoration project. These projects are shown in Figure 3 of the Main Report. The Lynnhaven Inlet navigation project provides for an entrance channel that is 10 feet deep and 150 feet wide extending 1 mile from that depth in the Chesapeake Bay to a mooring area and turning basin that is 10 feet deep, 1,250 feet long, and 700 feet wide in Lynnhaven Bay, just upstream from the Lesner Bridge at the mouth of the inlet. Virginia Beach Canal No. 2 has been constructed in the Southern part of the city providing flood control. The Lynnhaven Oyster Restoration consisted of the construction of 58 acres of oyster habitat in various locations in Linkhorn Bay, Broad Bay, the Eastern Branch, and the Lynnhaven Bay. Federal project activities are not anticipated to conflict with this environmental restoration Project.

7.2 NON-FEDERAL SPONSOR PROJECT LAND OWNERSHIPS

The City of Virginia, the Non- Federal Sponsor owns two (2) parcels of land and the Virginia Beach School Board owns one (1) parcel of land required for the Ecosystem Restoration Project Wetlands Easements. These three parcels comprise a total of 8.04 acres. They have no ownership rights in the state river bottom or leasehold interst in the river bottom.

8.0 NAVIGATIONAL SERVITUDE

Navigational Servitude does not apply to this project, due to there not being any commerce or navigation purpose for this Project.

9.0 PUBLIC LAW 91-646

Public Law 91-646 will apply to NFS acquisitions, and the NFS has been advised of P.L. 91-646 requirements, understands, and will fulfill those requirements. Pursuant to section 211(b) of the Act, "No payment or assistance under this title or title III of this Act shall be required to be made to any person or included as a program or project cost under this section, if such person receives a payment required by Federal, State, or local law which is determined by the head of the Federal agency to have substantially the same purpose and effect as such payment under this section." The NFS has provided confirmation that all payments made for acquisition of any parcels for the Project will include all necessary components under PL 91-646. It is therefore anticipated that payments made by the NFS will have substantially the same purpose and effect as such payment under PL 91-646.

10.0 INDUCED FLOODING

The intended effects of this project are not expected to cause flooding in this area.

11.0 REAL ESTATE COST ESTIMATE

The real estate costs for this project are shown on Exhibit B, which shows the wetlands baseline costs estimates and on Exhibit G which is the Chart of Accounts. The costs are estimated as follows:

a. Wetlands Restoration. The USACE Baltimore District, Real Estate Division, Technical Services Branch, Appraisal Staff has reviewed the wetlands interest requirement and provided a gross appraisal of the value for the wetlands real estate acquisitions, to be $71,880 based on use of the wetlands easement estate. This includes $13,474 for acquisition of public parcels; $50,789 for acquisition of private parcels; 15% contingency on acquisition of private parcels for $7,618; all totaling $71,880. The NFS administrative costs of $28,000 as estimated in the Gross Appraisal are not included in the $71,880. The Norfolk District's estimated real estate administrative cost is $49,840.28.

b. SAV, Scallop, Reef Habitat. No value is placed on the state-owned river bottom to be acquired under easement for the Project. However, because some parcels are currently under lease to third parties, the NFS must acquire the leasehold interests, either by donation, purchase or through eminent domain proceedings, as well as easements in perpetuity from the Commonwealth of Virginia. The NFS has estimated its total costs, including its, land acquisition, and all relocation and damages, at $450,000.00. The NFS has estimated its administrative cost at $50,000.00. The Norfolk District's estimated real estate administrative cost is $72,980.41.

c. Public Law 91-646 Relocation Cost

As explained in Section 9.0, there are no costs for PL 91-646 because any actions that would invoke PL 91-646 will necessarily include payment by the NFS that is required under Virginia State law that has substantially the same purpose and effect as payment under PL 91-646: "If any existing leases must be terminated or condemned, the NFS will utilize State eminent domain proceedings. Public Law 91-646 will apply to such eminent domain proceedings, and the NFS has been advised of P.L. 91-646 requirements, understands, and will fulfill those requirements. Pursuant to section 211(b) of the Act, 'No payment or assistance under section 210 or 305 shall be required or included as a program or project cost under this section, if the displaced person receives a payment required by the State law of eminent domain which is determined by such Federal agency head to have substantially the same purpose and effect as such payment under this section, and to be part of the cost of the program or project for which Federal financial assistance is available.'" Thus, pursuant to the application of section 211(b), there are no additional payments or assistance required under P.L. 91-646.

12.0 ZONING ENACTMENTS

There are no zoning changes or enactments that are needed for this project.

13.0 MINERAL ACTIVITY

No future mineral activities or other subsurface minerals or timber activities are involved in this project.

14.0 PUBLIC FACILITY RELOCATIONS

No utility or other public facilities relocations are required for the construction of this project.

15.0 NEPA, NHPA & HTRW

The environmental report prepared for this project indicated there are no hazardous, toxic or radioactive waste known to exist on the real property needed for this project.

16.0 ASSESSMENT OF NON-FEDERAL SPONSOR'S ACQUISITION CAPABILITY

The NFS is the City of Virginia Beach. The Norfolk District has worked with the City on several Local Cooperation Projects within the city, which include the Lynnhaven River Dredging Project, Rudee Inlet Dredging Project, the Virginia Beach Seawall and Beach Nourishment Project and the Sandbridge Beach Nourishment Project. Many of the intended sites for restoration of SAV, scallops and reef habitat are currently under lease to oyster harvesters by the VMRC. The City has affirmed its intent to acquire the real estate interests required to construct and maintain the Project, as required for local cooperation, and has confirmed that it possesses the necessary human and financial resources and legal authorities (including authority and willingness to condemn the leasehold interests) required to do so. An assessment of NFS's Real Estate acquisition capability and the NFS assurance letter are attached as Exhibit F.

17.0 PROJECT SCHEDULE

Real Estate Acquisition Schedule

Project Partnership Agreement for Construction	4 months post authorization
NTP with real property acquisition	1 month post-executed PPA date
Real Estate Acquisition Complete	2 years post-executed PPA date
Certification of Chief of Real Estate	1 month after completion of acquisition
Authorization for entry for construction	1 week
Construction	2 years

18.0 PUBLIC SUPPORT OR OPPOSITION

There is no known opposition for the current lands needed for the project.

19.0 RECOMMENDATION

a. It is recommended that this Real Estate Plan be approved with the condition that the proposed non-standard estates be submitted for review and approval during the Pre-Construction Engineering and Design Phase of the Project.

b. This report was prepared in accordance with Corps of Engineers Regulation 4051-12.

Prepared by:

David B. Parson
Realty Specialist

Approved by:

Donna Carrier-Tal
Chief, Real Estate Office

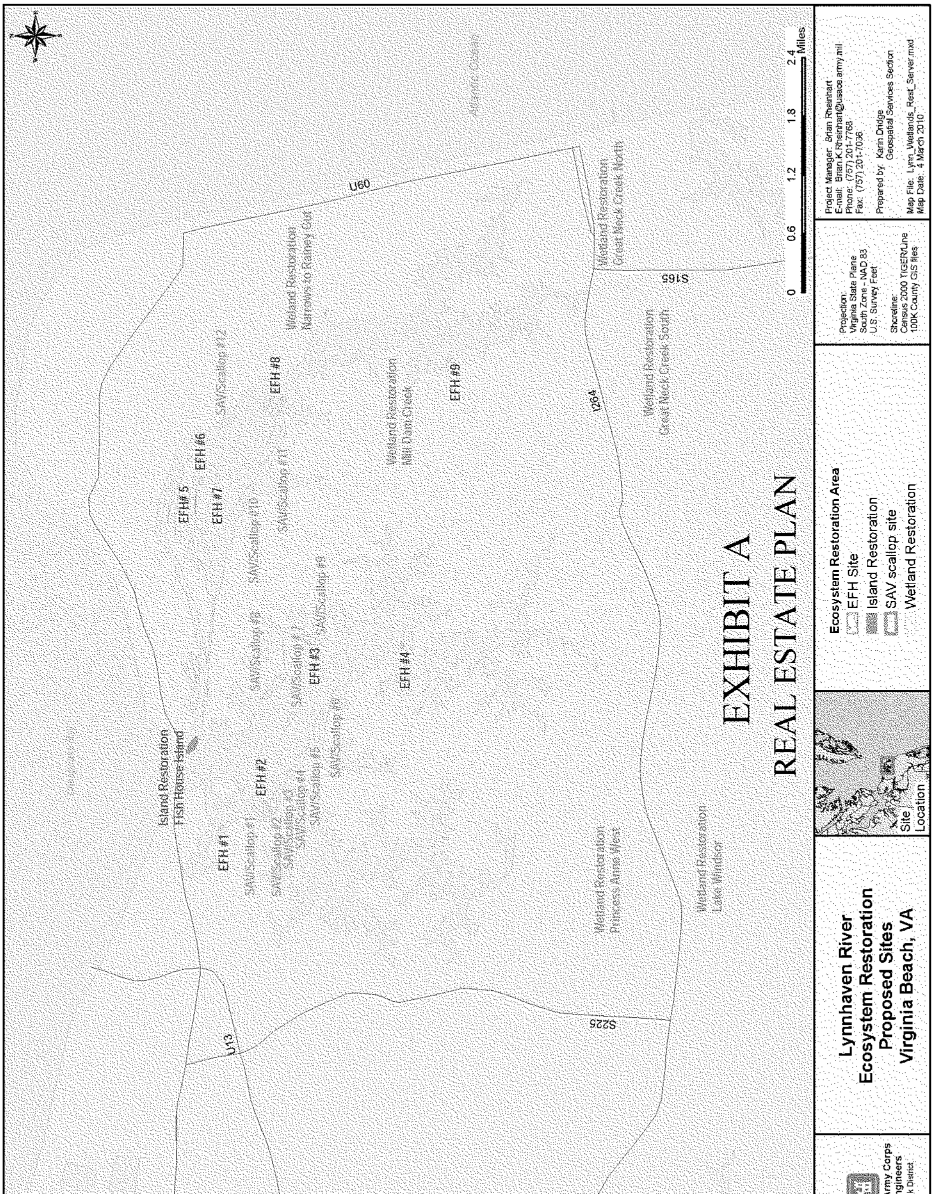


EXHIBIT A
REAL ESTATE PLAN
Lynnhaven River
Ecosystem Restoration
Proposed Sites
Virginia Beach, VA
US Army Corps
of Engineers
Norfolk District
Site
Location
Ecosystem Restoration Area
EFH Site
Island Restoration
SAV scallop site
Wetland Restoration
Projection:
Virginia State Plane
South Zone - NAD 83
U.S. Survey Feet
Shoreline:
Census 2000 TIGER/Line
100K County GIS files
Project Manager: Brian Rheinhart
E-mail: Brian.K.Rheinhart@usace.army.mil
Phone: (757) 201-7768
Fax: (757) 201-7036
Prepared by: Karin Dridge
Geospatial Services Section
Map File: Lynn_Wetlands_Rest_Server.mxd
Map Date: 4 March 2010
0
0.6
1.2
1.8
2.4
Miles
Island Restoration
Fish House Island
EFH #1
EFH #2
EFH #3
EFH #4
EFH# 5
EFH #6
EFH #7
EFH #8
EFH #9
Wetland Restoration
Narrows to Rainey Gut
Wetland Restoration
Mill Dam Creek
Wetland Restoration
Great Neck Creek North
Wetland Restoration
Great Neck Creek South
Wetland Restoration
Princess Anne West
Wetland Restoration
Lake Windsor
U60
U13
S165
S225
1264

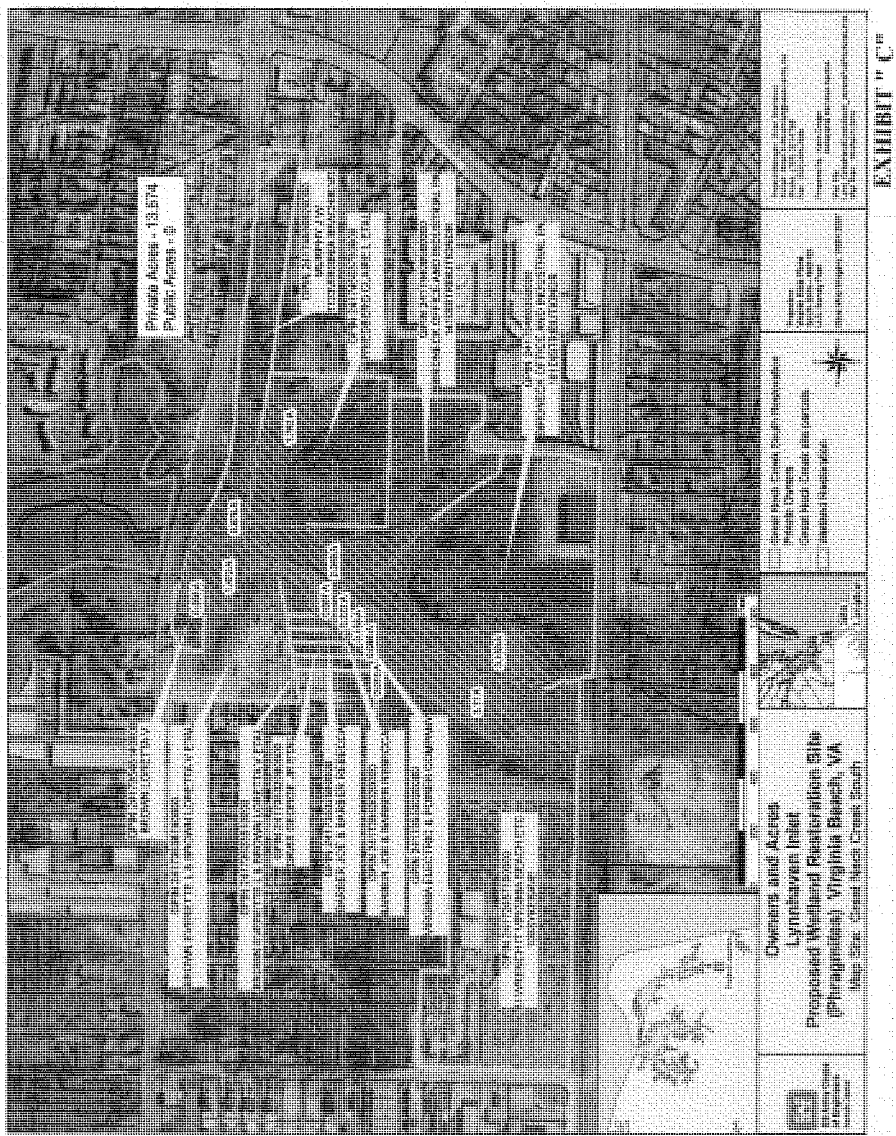
LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION STUDY

OWNERS OF PROPOSED WETLANDS EASEMENTS SITES

	LYNNHAVEN INLET					
	PROPOSED WETLAND RESTORATION SITE					
				Esmt	Easement	Easement
No	OWNER	GPIN	Location	Acreage	Public ACRES	Private Acres
1	Loretta Brown	24173548140000	Great Neck - S	0.206	None	0.206
2	Everette Brown	24173536150000	Great Neck - S	1.472	None	1.472
3	Everette Brown	24173523510000	Great Neck - S	0.015	None	0.015
4	George Davis	24173532080000	Great Neck - S	0.086	None	0.086
5	Joe Barber	24173532580000	Great Neck - S	0.156	None	0.156
6	Joe Barber	24173543020000	Great Neck - S	0.222	None	0.222
7	VEPCO	24173553020000	Great Neck - S	0.667	None	0.667
8	U Wrench It	24172457100000	Great Neck - S	3.110	None	3.110
9	J.W. Murphy	24174556920000	Great Neck - S	0.676	None	0.676
10	Claire Friedberg	24174504630000	Great Neck - S	1.762	None	1.762
11	Birdneck Office and Industrial Park	24174409680000	Great Neck - S	2.049	None	2.049
12	Birdneck Office and Industrial Park	24173466330000	Great Neck - S	3.153	None	3.153
13	No Data	0	Great Neck - S	0.138	None	0.138
	Great Neck South		**Subtotal**	**13.712**	**None**	**13.712**
14	Piper Apartments	24172782540000	Great Neck - N	5.041	None	5.041
15	CCT LC	24173643050000	Great Neck - N	2.918	None	2.918
16	EMS LLC	24173641740000	Great Neck - N	0.021	None	0.021
17	Foundation for Applied Christians	24173662520000	Great Neck - N	1.064	None	1.064
18	City of Virginia Beach	24173792600000	Great Neck - N	2.877	2.877	None
19	J W Murphy	24174588810000	Great Neck - N	2.410	None	2.410
20	Friendship Village	24174624720000	Great Neck - N	0.692	None	0.692
21	Ong Arenio M &Kyle T	24173697430000	Great Neck - N	0.841	None	0.841
22	John Owens	24173689810000	Great Neck - N	1.062	None	1.062
23	City of Virginia Beach	24173684430000	Great Neck - N	1.332	1.332	None
24	No Parcel Data			1.631	None	1.631
	Great Neck North		**Subtotal**	**19.889**	**4.209**	**15.680**
25	City of Virginia Beach	24083875950000	Mill Dam Creek	0.020	0.02	None
26	John Elko	24083899640000	Mill Dam Creek	0.830	None	0.83
27	Glenn Cherry	24083879560000	Mill Dam Creek	0.100	None	0.10
	Mill Dam		**Subtotal**	**0.950**	**0.02**	**0.93**
	Princess Anne West					
28	Virginia Beach Public Schools	14777694480000	Princess Anne West	3.815	3.815	None
	Grand Totals	**Public**	**$ 13,474**	8.04	Acres	
		Private	**$ 50,789**	30.32	Acres	
		Total	**$ 64,263**	38.36	Acres	

(Rounded 38.4 Acres)

EXHIBIT "B"


Owners and Acres
Lynnhaven Inlet
Proposed Wetland Restoration Site
(Pleasurehouse) Virginia Beach, VA
EXHIBIT "C"

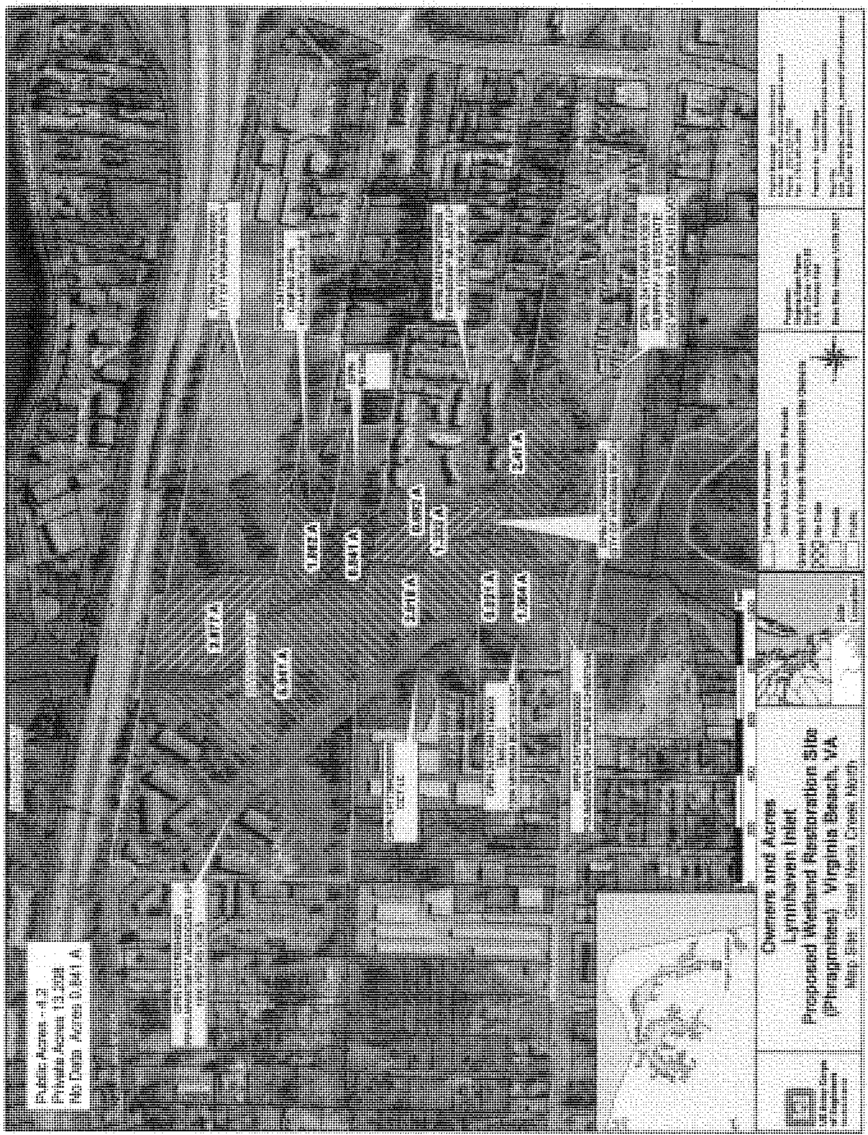

Owners and Acres
Lynnhaven Inlet
Proposed Wetland Restoration Site
(Phragmites) Virginia Beach, VA

EXHIBIT "C"

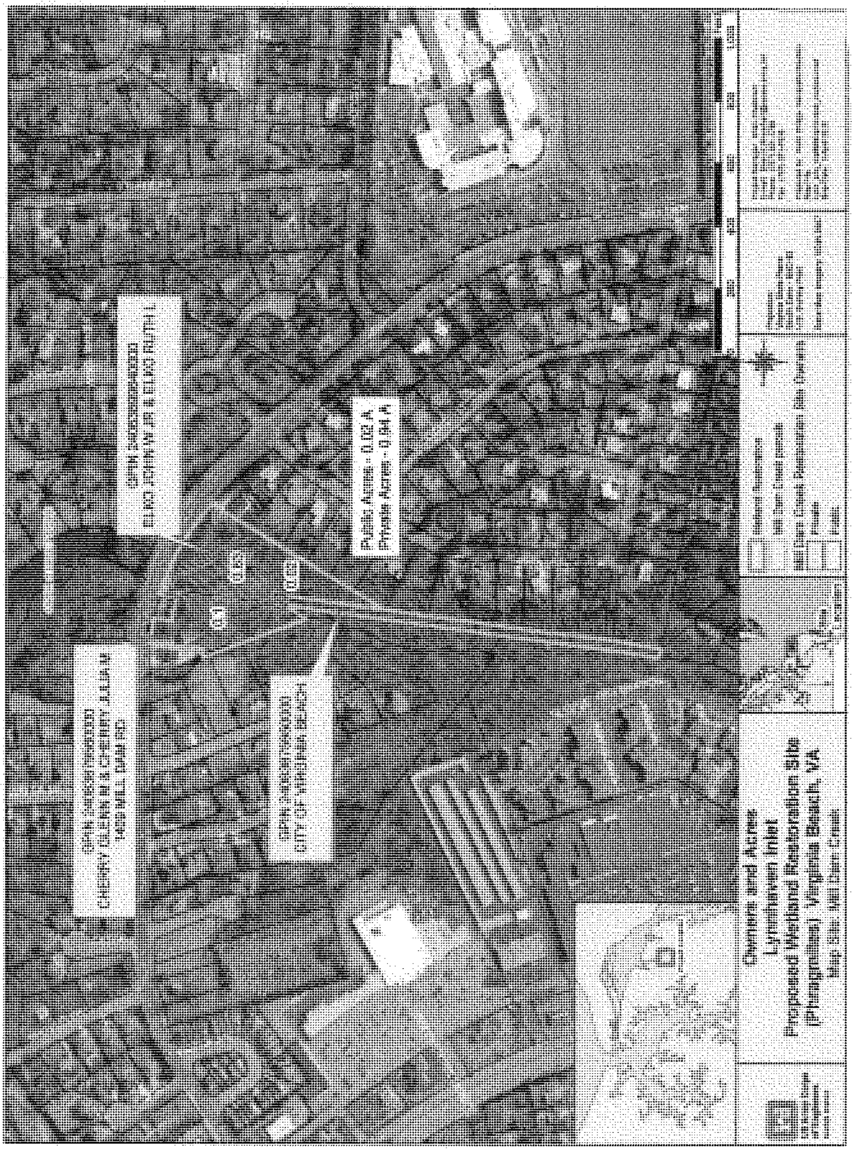
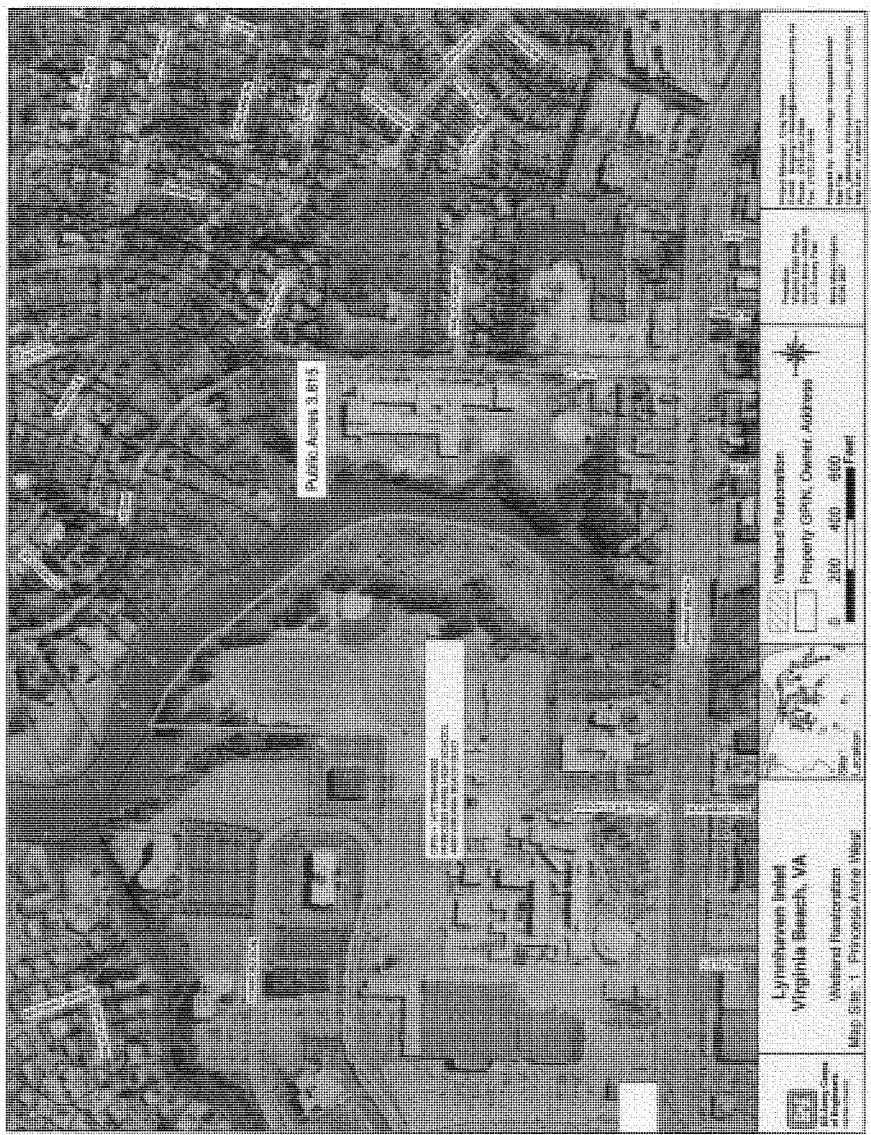

CHERRY GLENN M & CHERRY JULIA M
1409 MILL DAM RD
ELKO JOHN W JR & ELKO RUTH L
CITY OF VIRGINIA BEACH
Public Acres - 0.03 A
Private Acres - 0.94 A
Owners and Acres
Lynnhaven Inlet
Proposed Wetland Restoration Site
(Phragmites) Virginia Beach, VA
Map Site: Mill Dam Creek

EXHIBIT " C"



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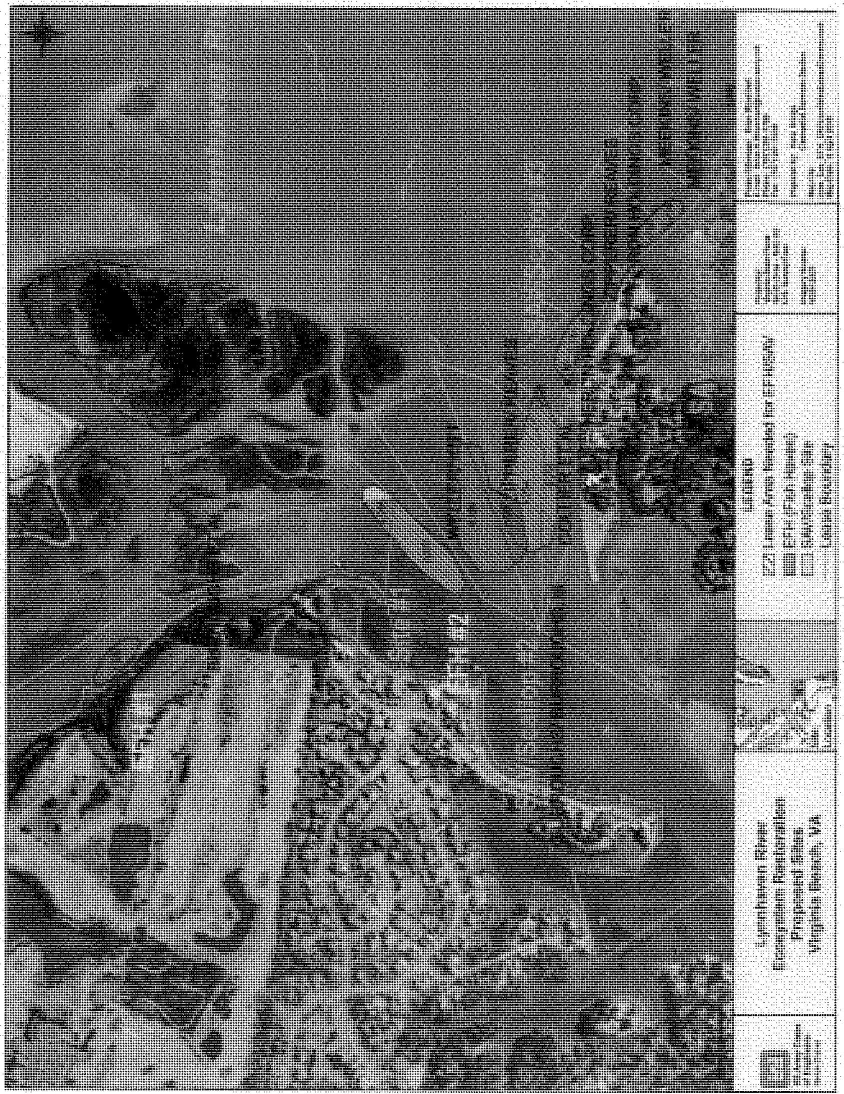

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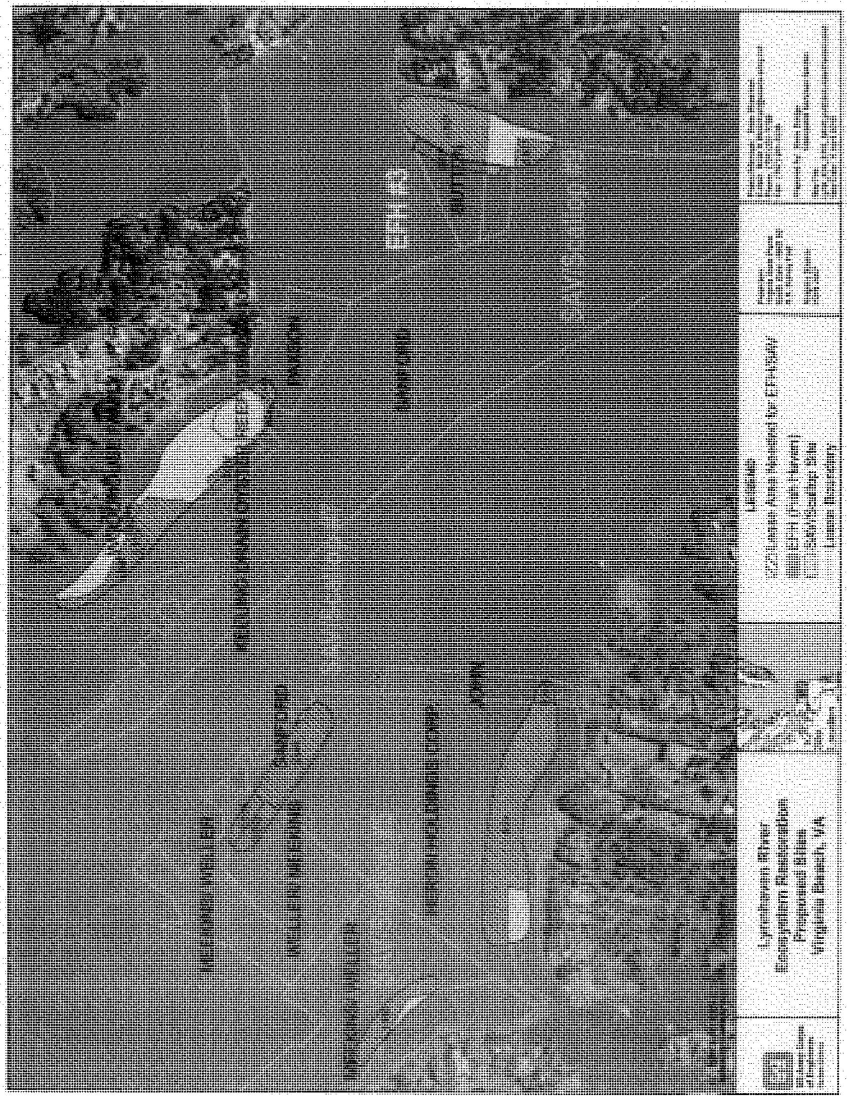

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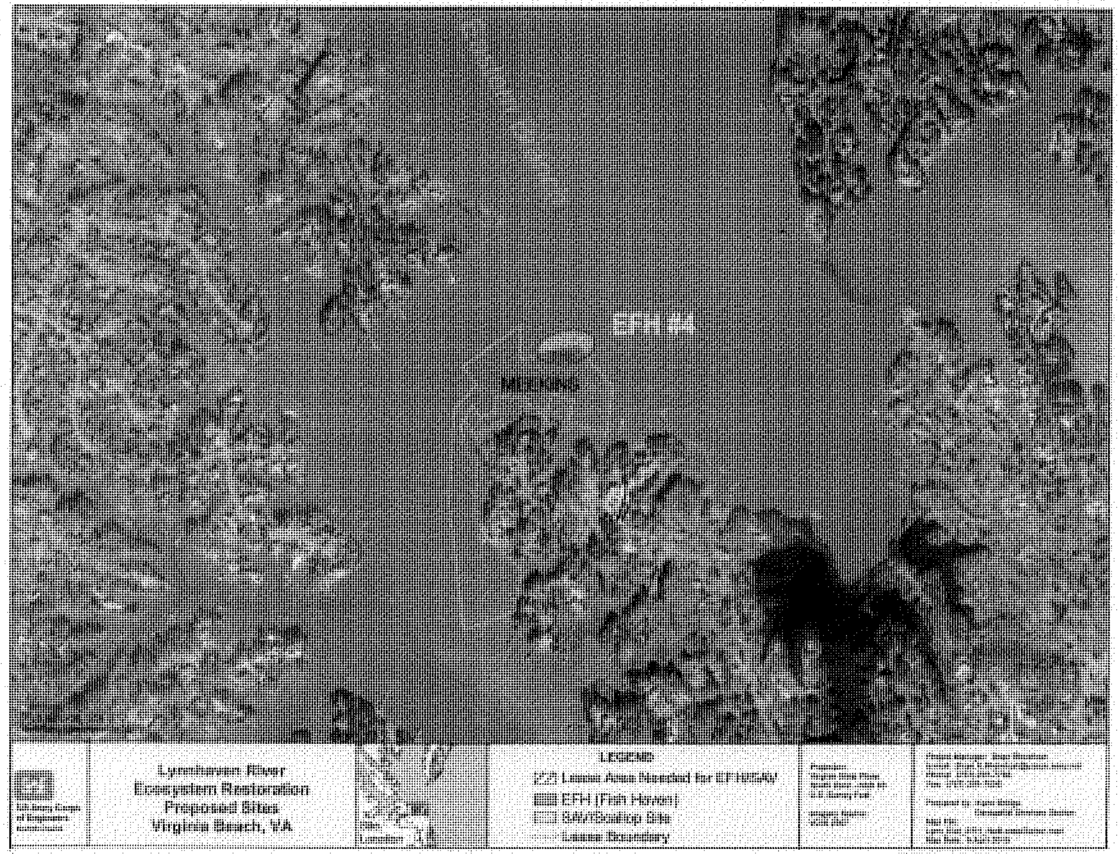

EFH #4
LEGEND
Lease Area Needed for EFH/SAV
EFH (Fish Haven)
SAV/Scallop Site
Lease Boundary
Lynnhaven River
Ecosystem Restoration
Proposed Sites
Virginia Beach, VA

EXHIBIT "D"

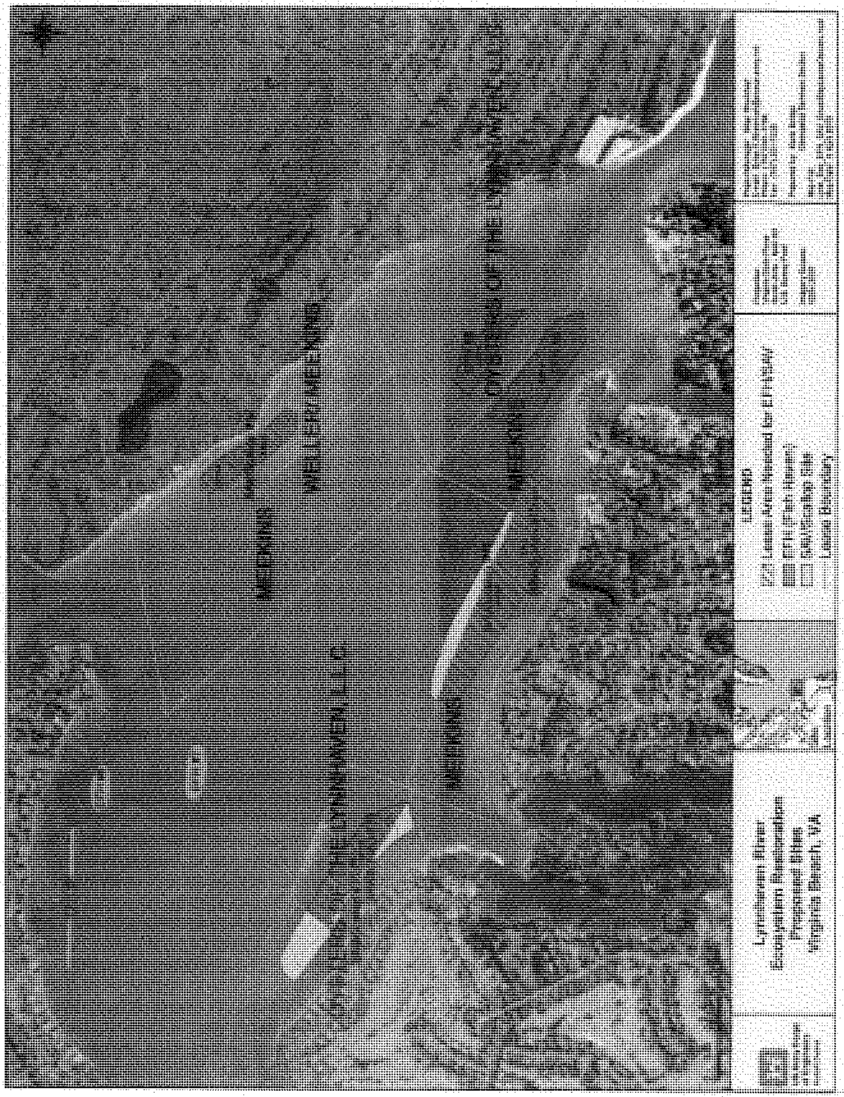


EXHIBIT "D"

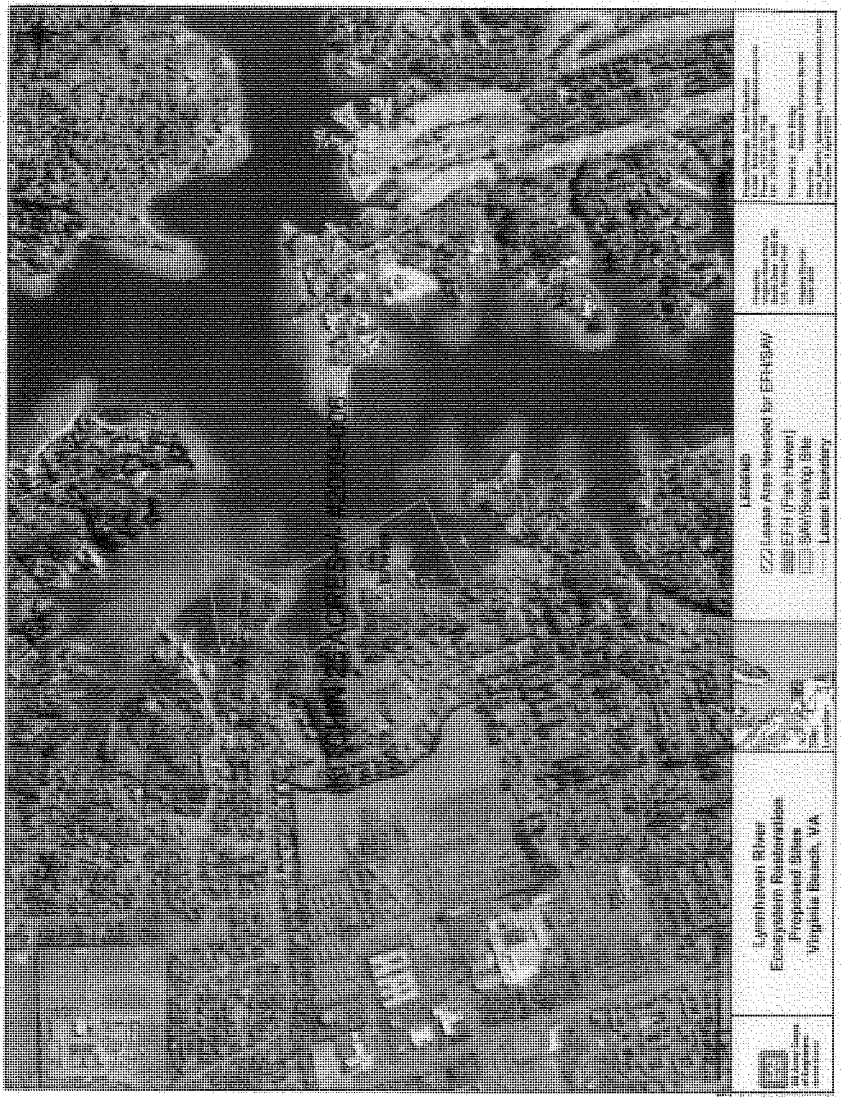


EXHIBIT 'D'

LYNNHAVEN OYSTER LEASE SITES

*	DESC_	Rest_Type	Site_Name	ACRES
1	Pleasure House Creek	Fish Reef Low Profile	Reef Habitat #1	1.142
2	Hill Point	Fish Haven	Reef Habitat #2	2.068
3	Hill Point	Fish Haven	Reef Habitat #3	4.797
4	Brock Cove	Fish Reef Low Profile	Reef Habitat #4	0.811
5	Brown Cove	Fish Reef Low Profile	Reef Habitat #5	0.527
6	Broad Bay Cove	Fish Haven	Reef Habitat #6	4.422
7	Broad Bay Cove	Fish Haven	Reef Habitat #7	9.884
8	Linkhorn Bay	Fish Reef High Profile	Reef Habitat #8	0.688
			TOTAL	24.339
9	Western Branch Lynn 1	SAV scallop site	SAV/Scallop #1	0.599
10	Western Branch Lynn 1	SAV scallop site	SAV/Scallop #1	3.033
11	Western Branch Lynn 2	SAV scallop site	SAV/Scallop #2	4.354
12	Western Branch Lynn 2	SAV scallop site	SAV/Scallop #2	2.215
13	Western Branch Lynn 2	SAV scallop site	SAV/Scallop #2	0.103
14	Eastern Branch Lynn 1	SAV scallop site	SAV/Scallop #3	0.149
15	Eastern Branch Lynn 1	SAV scallop site	SAV/Scallop #3	1.244
16	Eastern Branch Lynn 2	SAV scallop site	SAV/Scallop #4	0.492
17	Eastern Branch Lynn 2	SAV scallop site	SAV/Scallop #4	0.558
18	Eastern Branch Lynn 3	SAV scallop site	SAV/Scallop #5	1.981
19	Eastern Branch Lynn 4	SAV scallop site	SAV/Scallop #6	0.368
20	Eastern Branch Lynn 4	SAV scallop site	SAV/Scallop #6	9.31
21	Eastern Branch Lynn 5	SAV scallop site	SAV/Scallop #7	0.903
22	Eastern Branch Lynn 5	SAV scallop site	SAV/Scallop #7	0.718
23	Eastern Branch Lynn 5	SAV scallop site	SAV/Scallop #7	3.564
24	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.344
25	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	3.317
26	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.346
27	Brock Cove SAV	SAV scallop site	SAV/Scallop #9	4.357
28	Brock Cove SAV	SAV scallop site	SAV/Scallop #9	0.817
29	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.344
30	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.082
			TOTAL	39.198
31	Broad Bay 1	SAV scallop site	SAV/Scallop #10	7.469
32	Broad Bay 3	SAV scallop site	SAV/Scallop #11	14.072
33	Broad Bay 2	SAV scallop site	SAV/Scallop #12	1.721
34	Broad Bay 2	SAV scallop site	SAV/Scallop #12	3.853
35	Broad Bay 3	SAV scallop site	SAV/Scallop #11	3.227
			TOTAL	30.342
36	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.344
37	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	0.082
38	Eastern Branch Lynn 6	SAV scallop site	SAV/Scallop #8	1.668
			TOTAL	2.094
39	Broad Bay 1	SAV scallop site	SAV/Scallop #10	5.878
40	Broad Bay 3	SAV scallop site	SAV/Scallop #11	4.89
41	Broad Bay 3	SAV scallop site	SAV/Scallop #11	3.227
			TOTAL	13.995
			GRAND TOTAL	109.968
		EXHIBIT "E"		

LYNNHAVEN OYSTER LEASE SITES

#	DESC_	Rest_Type	Site_Name	ACRES	Value	
1	Pleasure H	Fish Reef Low Profile	Reef Habitat #1	1.142	$23,380.37	$20,473.18
2	Hill Point	Fish Haven	Reef Habitat #2	2.068	$42,338.54	$20,473.18
3	Hill Point	Fish Haven	Reef Habitat #3	4.797	$98,209.84	$20,473.18
4	Brock Cove	Fish Reef Low Profile	Reef Habitat #4	0.811	$16,603.75	$20,473.18
5	Brown Cov	Fish Reef Low Profile	Reef Habitat #5	0.527	$10,789.37	$20,473.19
6	Broad Bay	Fish Haven	Reef Habitat #6	4.422	$90,532.40	$20,473.18
7	Broad Bay	Fish Haven	Reef Habitat #7	9.884	$202,356.91	$20,473.18
8	Linkhorn B	Fish Reef High Profile	Reef Habitat #8	0.688	$14,085.55	$20,473.18
			TOTAL	24.339	$498,296.73	$20,473.18
						#DIV/0!
9	Western B	SAV scallop site	SAV/Scallop #1	0.599	$12,263.43	$20,473.17
10	Western B	SAV scallop site	SAV/Scallop #1	3.033	$62,095.15	$20,473.18
11	Western B	SAV scallop site	SAV/Scallop #2	4.354	$89,140.23	$20,473.18
12	Western B	SAV scallop site	SAV/Scallop #2	2.215	$45,348.09	$20,473.18
13	Western B	SAV scallop site	SAV/Scallop #2	0.103	$2,108.74	$20,473.20
14	Eastern Br	SAV scallop site	SAV/Scallop #3	0.149	$3,050.50	$20,473.15
15	Eastern Br	SAV scallop site	SAV/Scallop #3	1.244	$25,468.64	$20,473.18
16	Eastern Br	SAV scallop site	SAV/Scallop #4	0.492	$10,072.80	$20,473.17
17	Eastern Br	SAV scallop site	SAV/Scallop #4	0.558	$11,424.03	$20,473.17
18	Eastern Br	SAV scallop site	SAV/Scallop #5	1.981	$40,557.37	$20,473.18
19	Eastern Br	SAV scallop site	SAV/Scallop #6	0.368	$7,534.13	$20,473.18
20	Eastern Br	SAV scallop site	SAV/Scallop #6	9.31	$190,605.31	$20,473.18
21	Eastern Br	SAV scallop site	SAV/Scallop #7	0.903	$18,487.28	$20,473.18
22	Eastern Br	SAV scallop site	SAV/Scallop #7	0.718	$14,699.74	$20,473.18
23	Eastern Br	SAV scallop site	SAV/Scallop #7	3.564	$72,966.41	$20,473.18
24	Eastern Br	SAV scallop site	SAV/Scallop #8	0.344	$7,042.77	$20,473.17
25	Eastern Br	SAV scallop site	SAV/Scallop #8	3.317	$67,909.54	$20,473.18
26	Eastern Br	SAV scallop site	SAV/Scallop #8	0.346	$7,083.72	$20,473.18
27	Brock Cove	SAV scallop site	SAV/Scallop #9	4.357	$89,201.65	$20,473.18
28	Brock Cove	SAV scallop site	SAV/Scallop #9	0.817	$16,726.59	$20,473.18
29	Eastern Br	SAV scallop site	SAV/Scallop #8	0.344	$7,042.77	$20,473.17
30	Eastern Br	SAV scallop site	SAV/Scallop #8	0.082	$1,678.80	$20,473.17
			TOTAL	39.198	$802,507.71	$20,473.18
						#DIV/0!
31	Broad Bay	SAV scallop site	SAV/Scallop #10	7.469	$152,914.18	$20,473.18
32	Broad Bay	SAV scallop site	SAV/Scallop #11	14.072	$288,098.59	$20,473.18
33	Broad Bay	SAV scallop site	SAV/Scallop #12	1.721	$35,234.34	$20,473.18
34	Broad Bay	SAV scallop site	SAV/Scallop #12	3.853	$78,883.16	$20,473.18
35	Broad Bay	SAV scallop site	SAV/Scallop #11	3.227	$66,066.95	$20,473.18
			TOTAL	30.342	$621,197.23	$20,473.18
						#DIV/0!
36	Eastern Br	SAV scallop site	SAV/Scallop #8	0.344	$7,042.77	$20,473.17
37	Eastern Br	SAV scallop site	SAV/Scallop #8	0.082	$1,678.80	$20,473.17
38	Eastern Br	SAV scallop site	SAV/Scallop #8	1.668	$34,149.26	$20,473.18
			TOTAL	2.094	$42,870.84	$20,473.18
						#DIV/0!
39	Broad Bay	SAV scallop site	SAV/Scallop #10	5.878	$120,341.35	$20,473.18
40	Broad Bay	SAV scallop site	SAV/Scallop #11	4.89	$100,113.85	$20,473.18
41	Broad Bay	SAV scallop site	SAV/Scallop #11	3.227	$66,066.95	$20,473.18
			TOTAL	13.995	$286,522.15	$20,473.18
						#DIV/0!
			GRAND TOTAL	109.968	$2,251,394.66	$20,473.18

EXHIBIT "E"

ASSESSMENT OF NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITY

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes?
YES
Does the sponsor have the power of eminent domain for this project?
YES

b. Does the sponsor have "quiek-take" authority for this project?
YES

c. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? NO

d. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? YES: The NFS cannot condemn the oyster grounds owned by the Commonwealth of Virginia.

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? NO

b. If the answer to II.a. is "yes," has a reasonable plan been developed to provided such training? N/A

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? YES

d. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? YES

e. Can the sponsor obtain contractor support, if required in a timely fashion? YES

f. Will the sponsor likely request USACE assistance in acquiring real estate? NO: The City can condemn privately held leasehold interests, even if the lessor is the State. The Corps will not be required to conduct any required condemnations. .

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? YES

b. Has the sponsor approved the project/real estate schedule/milestone?

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? YES

b. With regard to this project, the sponsor is anticipated to be: highly capable/fully capable/moderately capable/marginally capable/insufficiently capable. (If the

EXHIBIT "F"

sponsor is believed to be "insufficiently capable," provide explanation)

V. Coordination:

a. Has this assessment been coordinated with the sponsor? Yes
b. Does the sponsor concur with this assessment? Yes

Prepared by:

David B. Parson
Realty Specialist

Approved by:

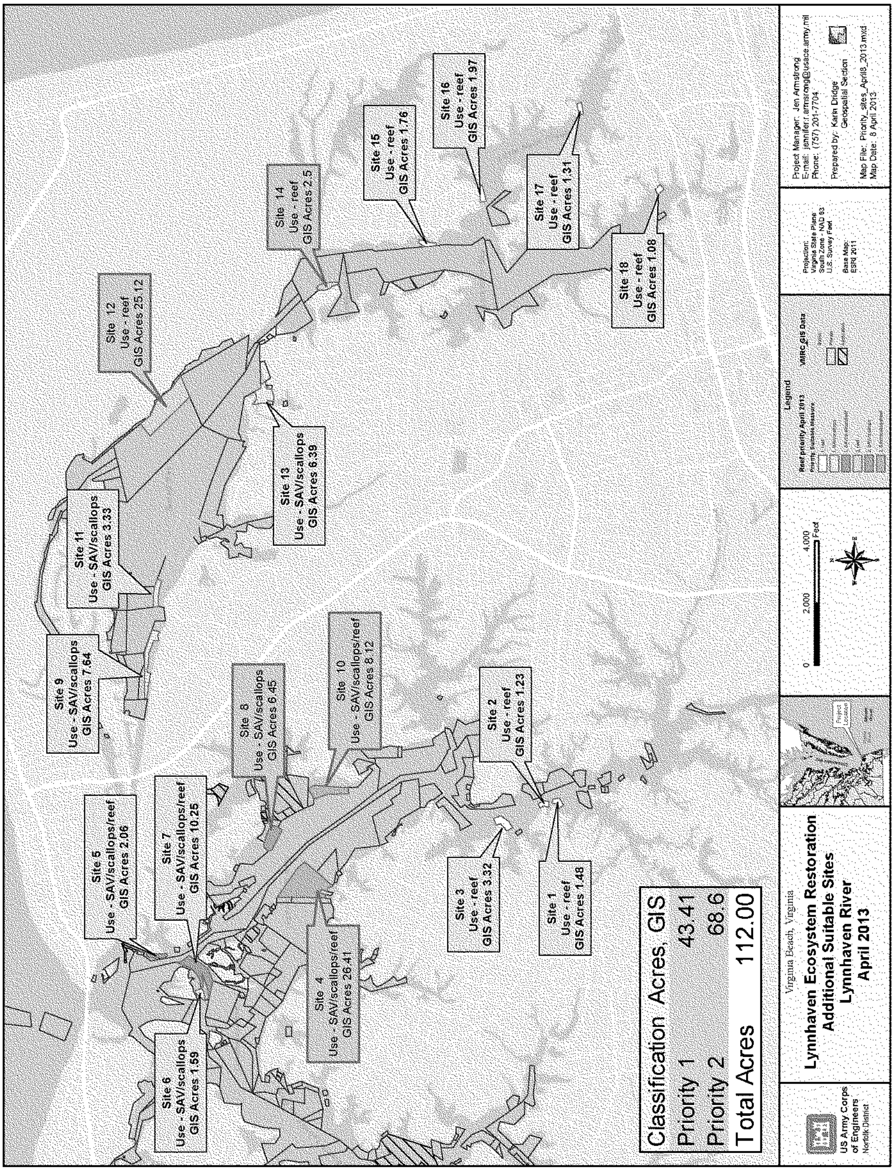
Donna Carrier-Tal
Chief, Real Estate Office

EXHIBIT "F"

Feasibility Study Cost Estimate-MCACES Format
Real Estate Acquisition Requirements

		Private			Commercial			Public			Requirement			
		#	$ each	req	#	$ each	req	#	$ each	req	Base	Contingency	Total	
0102-------	ACQUISITIONS													
010201---	By Government	0	0	0	0	0	0	0	0	0				
010202---	By Non-Federal Sponsor (NFS)	0	0	0	0	0	0	0	0	0	0	0	0	0
01020201	Survey and Legal Descriptions	56	305	17,080	9	305	2,745	4	305	1,220	21,045	3,157	24,202	0.15
01020102	Title Evidence	56	255	14,300	9	255	2,298	4	255	1,021	17,619	2,643	20,262	0.15
01020203	Negotiations	56	228	12,768	9	228	2,052	4	228	912	15,732	2,360	18,092	0.15
010203---	By Government on Behalf of NFS													
010204---	Review of NFS													
01020401	Survey and Legal Descriptions	56	500	28,000	9	500	4,500	4	500	2,000	34,500	5,175	39,675	0.15
01020402	Title Evidence	56	250	14,000	9	250	2,250	4	250	1,000	17,250	2,588	19,838	0.15
01020403	Negotiations	44	250	11,000	5	250	1,250	4	250	1,000	13,250	1,988	15,238	0.15
	SUBTOTAL										119,396	17,909	137,306	
0103-------	CONDEMNATIONS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010301---	By Government	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010302---	By Non-Federal Sponsor (NFS)	12	305	3,660	4	305	1,220	0	0	0	4,880	732	5,612	0.15
010303---	By Government on Behalf of NFS	0	0	0		0	0		0		0	0	0	0.15
010304---	Review of NFS	12	1,000	12,000	4	1,000	4,000	0	0	0	16,000	2,400	18,400	0.15
	SUBTOTAL										20,880	3,132	24,012	
0105-------	APPRAISALS	0	0	0	0	0	0	0	0	0	0	0	0	
010501---	By Government	0	0	0	0		0	0	0	0	0	0	0	
010502---	By Non-Federal Sponsor (NFS)	56	272	15,232	9	272	2,448	4	272	1,088	18,768	2,815	21,583	0.15
010503---	By Government on Behalf of NFS	0	0	0		0	0		0	0	0	0	0	0.15
010504---	Review of NFS	56	200	11,200	9	200	1,800	4	200	800	13,800	2,070	15,870	0.15
	SUBTOTAL										32,568	4,885	37,453	
0106-------	PL 91-646 ASSISTANCE	0	0	0	0	0	0	0	0	0	0	0	0	
010601---	By Government	0	0	0	0	0	0	0	0	0	0	0	0	
010602---	By Non-Federal Sponsor (NFS)	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010603---	By Government on Behalf of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010604---	Review of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
	SUBTOTAL										0	0	0	
0107-------	TEMPORARY PERMITS/LICENSES/RIGHTS-OF-WAY													
010701---	By Government	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010702---	By Non-Federal Sponsor (NFS)	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010703---	By Government on Behalf of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010704---	Review of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010705---	Other	0	0	0	0	0	0	0	0	0	0	0	0	0.15
010706---	Damage Claims	0	0	0	0	0	0	0	0	0	0	0	0	0.15
	SUBTOTAL										0	0	0	
0115-------	**REAL ESTATE PAYMENTS**													
011501---	Land Payments	0	0	0	0	0	0	0	0	0	0	0	0	
01150101	By Government	0	0	0	0	0	0	0	0	0	0	0	0	
01150102	By Non-Federal Sponsor (NFS)	56	7,453	417,373	9	7,453	67,078	4	7,453	29,612	514,263	321	514,584	0.00
01150103	By Government on Behalf of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.00
01150104	Review of NFS	56	200	11,200	9	200	0	4	200	800	12,000	0	12,000	0.00
														0.15
011502---	PL 91-646 Assistance Payments							0	0	0	0	0	0	15.00
01150201	By Government	0	0	0	0	0	0	0	0	0	0	0	0	0.15
01150202	By Non-Federal Sponsor (NFS)	0	0	0	8	0	0	0	0	0	0	0	0	0.15
01150203	By Government on Behalf of NFS	0	0	0	0	0	0	0	0	0	0	0	0	0.15
01150204	Review of NFS	0	0	0	8	0	0	0	0	0	0	0	0	0.15
011503---	Damage Payments	0	0	0	0	0	0 0	0	0	0	0	0	0	0.15
01150301	By Government	0	0	0	0	0	0 0	0	0	0	0	0	0	0.15
01150302	By Non-Federal Sponsor (NFS)	0	0	0	0	0	0 0	0	0	0	0	0	0	0.15
01150303	By Government on Behalf of NFS	0	0	0	0	0	0 0	0	0	0	0	0	0	0.15
01150304	Review of NFS	0	0	0	0	0	0 0	0	0	0	0	0	0	0.15
	SUBTOTAL										526,263	321	526,584	
Account 02 Facility/Utility Relocations (Construction cost only)												0	0	0.15
	REAL ESTATE ACQUISITION TOTAL										**$699,107**	**$26,248**	**$725,355**	

EXHIBIT "G"



Site 1
Use - reef
GIS Acres 1.48
Site 2
Use - reef
GIS Acres 1.23
Site 3
Use - reef
GIS Acres 3.32
Site 4
Use - SAV/scallops/reef
GIS Acres 26.41
Site 5
Use - SAV/scallops/reef
GIS Acres 2.06
Site 6
Use - SAV/scallops
GIS Acres 1.59
Site 7
Use - SAV/scallops/reef
GIS Acres 10.25
Site 8
Use - SAV/scallops
GIS Acres 6.45
Site 9
Use - SAV/scallops
GIS Acres 7.64
Site 10
Use - SAV/scallops/reef
GIS Acres 8.12
Site 11
Use - SAV/scallops
GIS Acres 3.33
Site 12
Use - reef
GIS Acres 25.12
Site 13
Use - SAV/scallops
GIS Acres 6.39
Site 14
Use - reef
GIS Acres 2.5
Site 15
Use - reef
GIS Acres 1.76
Site 16
Use - reef
GIS Acres 1.97
Site 17
Use - reef
GIS Acres 1.31
Site 18
Use - reef
GIS Acres 1.08
Classification Acres, GIS
Priority 1 43.41
Priority 2 68.6
Total Acres 112.00
US Army Corps of Engineers Norfolk District
Virginia Beach, Virginia
Lynnhaven Ecosystem Restoration
Additional Suitable Sites
Lynnhaven River
April 2013
0 2,000 4,000 Feet
Legend
Reef priority April 2013
VMRC GIS Data
Projection: Virginia State Plane South Zone - NAD 83 U.S. Survey Feet
Base Map: ESRI 2011
Project Manager: Jen Armstrong
E-mail: jennifer.r.armstrong@usace.army.mil
Phone: (757) 201-7704
Prepared by: Karin Dridge Geospatial Section
Map File: Priority_sites_April8_2013.mxd
Map Date: 8 April 2013

EXHIBIT "H"

APPENDIX F

CORRESPONDENCE

APPENDIX F

CORRESPONDENCE

TABLE OF CONTENTS

#42

City of Virginia Beach

VBgov.com

OFFICE OF THE CITY MANAGER
(757)385-4242
FAX (757) 385-5626
TDD 711

MUNICIPAL CENTER
BUILDING 1, ROOM 234
2401 COURTHOUSE DRIVE
VIRGINIA BEACH, VIRGINIA 23456-9001

May 9, 2012

Colonel Paul B. Olsen
District Commander
U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, VA 23510-1096

RE: Lynnhaven River Basin Restoration

Dear Colonel Olsen:

The City of Virginia Beach has reviewed the *Alternative Formulation Briefing Draft Feasibility Report and Integrated Environmental Assessment for the Lynnhaven River Basin, Virginia Beach, Virginia, Ecosystem Restoration Project* dated August 2011. We support and fully intend to participate in the project as described in the report. Further, we acknowledge our responsibilities as outlined in the Recommendations section of the report.

Implicit in our statement of support for the project is a willingness to enter into a Project Partnership Agreement with the Federal Government at the start of the next phase of the project, the Design/Implementation Phase. We understand the existing cost-sharing policies established in the Water Resources Development Act of 1986 (Public Law 99-662), as amended. Further, we understand that the total contribution for our share of the design and construction of this project is currently estimated to be $9,383,500, to include $447,000 for lands, easements, rights-of-way and relocations. The City of Virginia Beach has the financial capability to provide its share of the project cost through its normal budgetary and appropriation process. I am forwarding an executed Self-Certification Form for your use.

We are aware that this letter serves as an expression of intent and not a contractual obligation and that either party may discontinue the effort at any stage before construction begins. The City's participation is conditioned upon approval of the project and appropriation of necessary funds by the Virginia Beach City Council.

Should your staff have any questions, please have them call our Chief Water Resources Engineer, Phillip J. Roehrs, P.E., or the City's Virginia Pollutant Discharge Elimination System Administrator, William J. Johnston, P.E., at 757-385-4131, if you have any questions.

Sincerely,

James K. Spore

James K. Spore
City Manager

JKS/DLH/SGM/s

c: David L. Hansen, Deputy City Manager
Phillip A. Davenport, Interim Public Works Director
John E. Fowler, P.E., City Engineer
Phillip J. Roehrs, P.E., Chief Water Resources Engineer
William J. Johnston, P.E., VPDES Administrator

CITY OF VIRGINIA BEACH, VIRGINIA

NON-FEDERAL SPONSOR'S
SELF-CERTIFICATION OF FINANCIAL CAPABILITY
FOR DECISION DOCUMENTS

I, James K. Spore, do hereby certify that I am the City Manager of the City of Virginia Beach (the "Non-Federal Sponsor); that I am aware of the financial obligations of the Non-Federal Sponsor for the AFB Draft Feasibility Report and Integrated Environmental Assessment, Lynnhaven River Basin Ecosystem Restoration, Virginia Beach, Virginia August 2011; and that the Non-Federal Sponsor will have the financial capability to satisfy the Non-Federal Sponsor's obligations of the project. I understand that the Government's acceptance of this self-certification shall not be construed as obligating either the Government or the Non-Federal Sponsor to implement a project. The City's participation is conditioned upon approval of the project and appropriation of necessary funds by the Virginia Beach City Council.

IN WITNESS WHEREOF, I have made and executed this certification this 9th day of May, 2012.

BY: ______________________

TITLE: City Manager

DATE: May 9, 2012

City of Virginia Beach

VBgov.com

OFFICE OF THE CITY MANAGER
(757) 385-4242
FAX (757) 427-5626
TTY: 711

MUNICIPAL CENTER
BUILDING 1
2401 COURTHOUSE DRIVE
VIRGINIA BEACH, VA 23456-9001

April 10, 2013

Colonel Paul B. Olsen
District Engineer
Norfolk District Corps of Engineers
803 Front Street
Norfolk, Virginia 23510-1096

RE: Lynnhaven River Basin Ecosystem Restoration

Dear Colonel Olsen:

The City of Virginia Beach greatly appreciates the work done by the Corps of Engineers in developing the final feasibility study for the Lynnhaven River Basin Ecosystem Restoration project. We are pleased that the project is nearing readiness for consideration by Congress for authorization.

We understand that concerns exist regarding the City's ability to accomplish the real estate acquisition that may be necessary for the project. Please be assured that we have reviewed the potential real estate requirements identified in the District's letter dated March 12, 2013. We acknowledge that the provision of all real estate interests necessary for the construction, operation, maintenance, repair, rehabilitation, and replacement of the project will be the responsibility of the City of Virginia Beach as the Non-Federal Sponsor for this project It is understood that the procurement of real estate interests may include acquiring or terminating existing oyster leases, acquiring permanent real estate interests from private and public property owners for wetlands restoration, and securing permanent easements over state-owned river bottoms to support the parts of the project involving submerged aquatic vegetation restoration, bay scallops reintroduction, and reef habitat creation.

Please be assured that the City of Virginia Beach has the legal authority, technical capability, and financial resources to acquire the necessary real estate interests. The City of Virginia Beach supports and fully intends to provide the necessary real estate interests for the project features identified in the recommended plan following the execution of a Project Partnership Agreement (PPA) for construction of the project.

Colonel Paul B. Olsen
Lynnhaven River Basin Ecosystem Restoration
April 10, 2013
Page 2

Should the occasion arise, the City of Virginia Beach understands, acknowledges, and accepts the risks associated with acquiring any necessary real estate interests before the execution of the PPA and before the formal notice to proceed with real estate acquisition.

Please understand that this letter serves as an expression of intent and is not a contractual obligation and that either party may discontinue the effort at any stage before construction begins.

In closing, our relationship with the Corps of Engineers and the Norfolk District extends back through our entire 50-year history as the City of Virginia Beach. We have been the non-federal sponsor on a number of significant and important Civil Works projects. The provision of the required real estate has always been a non-federal responsibility, and I hope and trust a review of our past, and current, partnerships completely supports our capability statements herein.

We again would like to express our gratitude to the entire Corps of Engineers organization for bringing this project toward fruition.

Sincerely,

James K. Spore
City Manger

c: Honorable Mayor William D. Sessoms, Jr.
and Members of City Council
Mark Stiles, City Attorney

Comments on Lynnhaven Draft Feasibility Report and Integrated Environmental Assessment Released for Public Review April 26 – May 26

Comments on the Draft Feasibility Study and Integrated EA were received from only two external organization, the Virginia Institute of Marine Science (VIMS) and the Virginia Marine Resource Commission. VIMS sent two letters – after the first was received, the Norfolk District PDT met with VIMS to discuss their concerns. VIMS then sent a second letter based on that discussion. The comments in those letters are summarized below along with District response.

Commenter: VIMS #1
Although the objectives expressed in the Report are commendable, our review has revealed shortcomings in the proposed strategies that could significantly compromise the project's success.

USACE RESPONSE 1: Based on these concerns, USACE and VIMS had a meeting on May 31st at VIMS. We appreciate the discussion with VIMS scientists, and look forward to working together as we move forward into PED. We received e follow-on letter dated 20 June 2013 which provides specific paths forward for the identified issues, as well as the statement "VIMS supports these types of focused efforts and we support the Norfolk District's desire to enhance the Lynhaven River Basin." USACE discusses each concern in more detail in the comments and responses below, and believes that the majority of the issues are addressed through a combination of adaptive management, some revisions to the report that have occurred, and a continued commitment to seek the guidance of VIMS on technical issues as we move forward.

Commenter: VIMS #1
Though the Report states that water quality improvement is not a primary objective of this project, much of the rationale for the proposed activities described in sections 3 & 4 appears to be based upon presumed water quality benefits resulting from these activities. It is important for all stakeholder groups to understand that, even if complete success were achieved for all elements of the proposal, the enhanced resources likely will contribute little in addressing the required total maximum daily loads (TMDL) nutrient reductions in the Lynnhaven watershed.

USACE RESPONSE 2: Based on this comment as well as our internal USACE review, the discussion of water quality has been adjusted significantly so that it is very clear that this project was not formulated for water quality improvements. The locality is entirely responsible for required water quality improvements through separate projects and programs. However, incidental water quality benefits are anticipated as a result of the project.

Commenter: VIMS #1
In summary, we conclude that the proposed projects have a low likelihood of successfully achieving the stated objectives for the following reasons.

> Existing water quality conditions and future sea level and water temperature scenarios do not favor the establishment, proliferation, and stability of submerged aquatic vegetation (SAV). This ultimately compromises the objective of establishing healthy populations of bay scallops, which depend on SAV beds for nursery areas.

USACE RESPONSE 3: USACE disagrees that the required water quality conditions and temperature do not favor SAV establishment, proliferation and stability. SAV has been abundant in the Lynnhaven at many times, and is currently established in small pockets in the Lynnhaven, though not in large enough areas to develop a self-sustaining population. However, based on discussions with VIMS staff, the implementation and adaptive management plans will be adjusted to stagger the planting of the SAV and ensure that success criteria are being met for several years before scallops are attempted.

> **COMMENT:** Given the ephemeral nature of Ruppia maritima and high inter-annual variability in persistence of newly established Zostera marina beds, we strongly recommend that bay scallop restoration not be initiated until large SAV beds dominated by eelgrass show 3-5 years of sustained presence at healthy densities.

USACE RESPONSE 4: The implementation and adaptive management plans have been adjusted to reflect a sustained presence of SAV before scallops are introduced. For the SAV and scallops, pilot programs (test plots) will be implemented, as suggested, before larger-scale restoration is attempted.

> **COMMENT:** Most notably, bay scallop introduction/restoration is a very young science in Virginia, and without large native populations from which to harvest and transplant there are significant supply issues that have not been addressed in the Report, including the acquisition and maintenance of broodstock with sufficient genetic diversity, quarantine facilities for holding spawning stocks brought from other regions (which can contain epibionts not native to Virginia), and the production facilities for producing the 100's of thousands, if not millions, of scallops that will likely be required to establish a self-sustaining population.

USACE RESPONSE 5: Noted. USACE concurs that such a large-scale restoration will indeed inherently have supply concerns. This has already been considered in the cost estimates and risk assessments, and will continue to be a consideration as the project moves forward into PED.

> **COMMENT:** The Report proposes the planting of eelgrass (Zostera marina) and widgeongrass (Ruppia maritima) seeds. While VIMS faculty and staff have significant understanding of the requirements for restoring eelgrass, very little is known for widgeongrass.

USACE RESPONSE 6: Noted. However, there are benefits to including several potential types of grasses, and the adaptive management plan will allow the project to adjust based on the success of each species at various locations.

> **COMMENT:** The transformation of intertidal salt marshes from common reed (Phragmites australis) to native Bay marsh species that primarily includes saltmarsh cordgrass (Spartina alterniflora) will likely not result in enhanced ecosystem function and may result in short-term loss of ecosystem function. Left alone these areas will surely undergo natural progression to dominance by saltmarsh cordgrass over time due to sea level rise.

USACE RESPONSE 7: There is differing opinions in the scientific communities on the benefits and detriments of phragmites. USACE feels confident in the phragmites eradication plan and has calculated the benefits and feels strongly that this is an appropriate restoration technique.

> **COMMENT:** Reefs are proposed to be constructed using expansive applications of formed concrete and the accompanying assumption that natural fouling, especially by oysters, will create unique Essential Fish Habitat (EFH). Neither the proposed locations nor densities of the reefs were established with the aid of existing hydrodynamic and water quality models developed specifically for the Lynnhaven River and thus may not be positioned for the optimum development of reef communities, including oysters.

USACE RESPONSE 8: We do not concur with this comment. The reefs were placed using results from several previous model runs, although it is true that only limited model runs were completed (due to funding constraints). Also, the locations of all measures were also dependent on available bottom as well as appropriate substrate and hydrodynamics. As stated previously, USACE will continue to work with VIMS as we move forward into implementation.

Commenter: VIMS #1

The management approach described in the Report is not an iterative process that builds on the monitoring information base, but rather assesses the outcomes of the monitoring and relies on the lone strategy of moving the activities to another location in the watershed if monitoring data do not meet expectations. The aggressive approach outlined in the Report has an overall low likelihood of success. It is our collective opinion that an adaptive management strategy should be considered in which the chosen, or alternative, actions of the project are initiated on smaller scales over longer timeframes, and are either increased in stages, altered, or even abandoned based on monitoring data that address specific questions and issues.

USACE RESPONSE 9: Based on this and other comments, the adaptive management and implementation plans have been modified. The adaptive management has been expanded, and includes pilot studies (test plots) to try small-scale implementation before large-scale restoration is established.

Commenter: VIMS #2
First, I would like to thank you for the opportunity to discuss the Lynnhaven Report and our comments in greater detail with you and your staff on May 31st. The conversations were productive in helping us better understand the flexibility that you have at later stages to modify the design details and employ adaptive management.

USACE RESPONSE 10: We found the meeting to be very productive and appreciate the VIMS staff taking the time to meet with USACE on this important project. We look forward to continuing to work together as we move towards implementation.

Commenter: VIMS #2
It is our opinion that if you are able to implement the SAV restoration in a manner consistent with our discussions, your likelihood of success with this phase of the project will be substantially enhanced. Specifically, we recommend (1) that site selection be driven by current water quality, depth and bottom conditions and (2) that small test plots be established initially to validate survival for a full year prior to larger scale seeding of an area. Concurrent monitoring of water quality at the test plot sites would provide valuable insights into to the conditions responsible for the success or failure of individual plots.

USACE RESPONSE 11: We will be doing pilot studies (test plots) before large scale restoration is attempted. We cannot do water quality monitoring, as that is a responsibility of the locality, but we will use available water quality monitoring data. The site selection was based on appropriate substrate, depth, hydrodynamics and available bottom. We will continue to use the best available information, as well as seek advice from VIMS, as we move forward towards implementation.

Commenter: VIMS #2
We stand by our previous recommendation that bay scallop restoration not proceed until eelgrass beds have persisted for a minimum of 3 years and recommend, even in that case, that serious consideration be given to the scale of the grass beds that have been established. Though we do not know the minimum grass bed size required to support a sustainable population of bay scallops, it is clear that more than a few small patches will be necessary.

USACE RESPONSE 12: The implementation and adaptive management plan has been adjusted to allow for pilot studies of the measures as well as several years of successful SAV before scallops are initiated.

Commenter: VIMS #2
We do not question the technical feasibility of deploying reef balls or that oysters and other epibenthic organisms will attach to and grow on these structures. We recommend, however, that careful consideration be given to the specific ecosystem responses that are anticipated from this activity, how those differ from or enhance those resulting from the substantial amount of anthropogenic hard substrate already in the system, and how these specific responses will be measured.

USACE RESPONSE 13: Noted, however the stated desired end goal is an increase in secondary production. Some examples are noted in the report, but further identification of potential epibenthic organisms was not included in this study. USACE commits to continuing to discuss this topic with VIMS.

Commenter: VIMS #2
Watershed-scale restoration and enhancement efforts are an important part of Chesapeake Bay restoration and, if designed and implemented properly, can provide real and significant benefits to the littoral marine environment and the local watershed-based community. Our previous comments address only the feasibility of the proposed technical elements and should not be interpreted as a commentary on the project's intent or concept. VIMS supports these types of focused efforts and we support the Norfolk District's desire to enhance the Lynnhaven River basin. We are well aware that this is a broadly shared desire as evidenced by the strong community support for a healthier Lynnhaven River, which ultimately is critical to project acceptance, momentum, and success.

USACE RESPONSE 14: Thank you and we look forward to continuing to coordinate with you on this important project.

Commenter: VMRC

Any proposal to impact, encroach, fill, or dredge such submerged bottomlands must first garner an exemption or permit from the Commission. For every permit request the Commisssion reviews the proposal and attempts to identify potential benefits and detriments for the marine resource and the public utilizing and enjoying such resource.

USACE RESPONSE 15: Noted. We look forward to coordinating with VMRC on this project.

Commenter: VMRC
The proposal to install concrete oyster reefs and establish SAV habitat areas in various areas of the Lynnhaven system may conflict with current shellfish-lease activities, as most of the lower Lynnhaven system is currently leased for commercial shellfish production. Any such request to impact existing leases will require a notification to the record leaseholder(s), and confirmation that they agree with the proposal on their lease. Although it may be legally possible for the locality to acquire or condemn existing private leases for governmental purposes, it is unclear at this time if the City of Virginia Beach will support such initiatives for the "restorative" purposes identified in this study.

USACE RESPONSE 16: Noted. We look forward to working with VMRC on this project. The City of Virginia Beach does support restoration initiatives, as evidenced by their letter of support and their continued partnership on all aspects of this project.

Commenter: VMRC
Along with your proposed SAV habitat areas, you have proposed to introduce scallops as a new marine species in the Lynnhaven. Notwithstanding the fact that the proposed SAV must succeed and thrive for a few growing seasons before scallops can be introduced, such a species introduction may raise additional management issues. Proposed SAV areas and future scallop production, although signs of a healthy ecosystem, may further limit existing shellfish aquaculture activities as well as public access to areas within the Lynnhaven system. The benefits and detriments of such a proposal will need to be ultimately weighed by the Commission before a permit decision can be reached.

USACE RESPONSE 17: The Bay Scallop is a re-introduction in the Lynnhaven, as there is evidence that it was historically present. VMRC staff has been and will continue to be a member of the project steering committee, and it is anticipated that any concerns will be brought about first through this venue. USACE looks forward to working with VMRC on this project as it moves forward.

Commenter: VMRC
We note that VIMS has pointed out several items of concern with the overall projected success of the concrete reefs, SAV, and even scallop populations.

USACE RESPONSE 18: Please see USACE Response #14 above. VIMS and USACE held a meeting on May 31, 2013 and talked though many of the issues. Although VIMS still has concerns with some portions of the proposal, USACE has adjusted the implementation and adaptive management plans to help reduce the risk on some of these project features. In addition, many of the recommendations by VIMS can be considered and incorporated as appropriate during the PED stage.

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Virginia Institute of Marine Science

20 May, 2013

Janet Cote
Ecologist
US Army Corps of Engineers
Norfolk District
Planning and Policy Branch
803 Front Street
Norfolk, VA 23510-1096

Dear Ms. Cote:

This letter communicates the collective analysis of the *Lynnhaven River Basin Ecosystem Restoration Draft Feasibility Report and Integrated Environmental Assessment* (the Report) by faculty and staff of the Virginia Institute of Marine Science (VIMS). The Report outlines an ambitious plan to establish stable and sustainable populations of native estuarine fishery and vegetation resources that could provide beneficial ecosystem services towards improved estuarine habitat and water quality. VIMS' long history of comprehensive research and resource management experience in the greater Chesapeake Bay region includes long-term and continuing attention specific to the Lynnhaven watershed, which began with water quality surveys requested by the State Water Control Board in 1961. We trust that the following observations and comments can add value to the objectives and approaches proposed in the Report.

Although the objectives expressed in the Report are commendable, our review has revealed shortcomings in the proposed strategies that could significantly compromise the project's success. Though the Report states that water quality improvement is not a primary objective of this project, much of the rationale for the proposed activities described in sections 3 & 4 appears to be based upon presumed water quality benefits resulting from these activities. It is important for all stakeholder groups to understand that, even if complete success were achieved for all elements of the proposal, the enhanced resources likely will contribute little in addressing the required total maximum daily loads (TMDL) nutrient reductions in the Lynnhaven watershed. In summary, we conclude that the proposed projects have a low likelihood of successfully achieving the stated objectives for the following reasons. Existing water quality conditions and future sea level and water temperature scenarios do not favor the establishment, proliferation, and stability of submerged aquatic vegetation (SAV). This ultimately compromises the objective of establishing healthy populations of bay scallops, which depend on SAV beds for nursery areas. The transformation of intertidal salt marshes from common reed (*Phragmites australis*) to native Bay marsh species that primarily includes saltmarsh cordgrass (*Spartina alterniflora*) will likely not result in enhanced ecosystem function and may result in short-term loss of ecosystem function. Left alone these areas will surely undergo natural progression to dominance by saltmarsh cordgrass over time due to sea level rise. Reefs are proposed to be constructed using expansive applications of formed concrete and the accompanying assumption that natural fouling, especially by oysters, will create unique Essential Fish Habitat (EFH). Neither the proposed locations nor densities of the reefs were established with the aid of existing hydrodynamic and water quality models developed specifically for the Lynnhaven River and thus may not be positioned for the optimum development of reef communities, including oysters. A more detailed synopsis of our analyses follows.

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Submerged Aquatic Vegetation

VIMS' continuing involvement in SAV transplanting/restoration (Orth *et al.* 2010, Orth *et al.* 2012) began in 1978, and Bay-wide SAV distribution has been monitored by VIMS since 1984 (http://web.vims.edu/bio/sav/index.html). Additionally, VIMS faculty and staff were principal contributors in the development of Virginia's water quality standards for water clarity, which are based on habitat requirements for SAV. Based on our collective experience we are well aware of the challenges associated with maintaining current SAV resources, and establishing new sustainable populations. Indeed, there are few successful SAV restorations in Chesapeake Bay relative to the number and scale of attempts, which suggests that any attempt to establish SAV should be approached carefully and with buffered expectations. These expectations should especially be considered with respect to sea level rise and increasing water temperatures in the mid-Atlantic region and Chesapeake Bay. The Report proposes the planting of eelgrass (*Zostera marina*) and widgeongrass (*Ruppia maritima*) seeds. While VIMS faculty and staff have significant understanding of the requirements for restoring eelgrass, very little is known for widgeongrass. Widgeongrass beds can undergo large annual changes in size and distribution (i.e. it is considered a "boom or bust" species) in Chesapeake Bay, including Broad Bay, as shown in the VIMS aerial surveys. Similar to eelgrass, widgeongrass has beneficial functions for water quality and habitat; however, it is entirely possible that widgeongrass could show initial success followed by large-scale die-off with the likelihood of no return.

Water quality characteristics in many areas within the Lynnhaven system show significant challenges for SAV. Our annual monitoring has never shown SAV to occur in the Lynnhaven River. Modest yet declining populations have been observed in Broad Bay since 1984, and VIMS' monitoring (http://web.vims.edu/bio/sav/SegmentAreaChart.htm) shows a maximum of approximately 110 acres in 1986 and 1994. These data suggest that habitat requirements for SAV are not now being met in many areas throughout this system. The Report appears to overestimate the existing habitat conditions relative to SAV success, and we do not agree that the Lynnhaven system currently shows similarities in habitat and water quality with the Virginia Coastal Bays where we have restored approximately 4,800 acres of eelgrass. The target sites for SAV establishment were based on bottom condition and a 1971 aerial survey unknown to VIMS faculty and staff that sets the amount of SAV in the Lynnhaven watershed at 175 acres. A hydrodynamic model was referenced to infer seed dispersal and bed spreading once populations were established. Bottom conditions and historical abundance and distribution have been used to guide past SAV restoration efforts with marginal success. Moreover, we note that two of the largest areas identified in Broad Bay for SAV transplanting appear to be in water depths too deep to support SAV. If the decision is made to move forward with SAV restoration, we strongly recommend that an emphasis be placed on monitoring SAV habitat requirements during the growing season for several years prior to seeding or transplanting. Should these data show that suitable habitat requirements exist, we then recommend that small-scale restoration efforts be undertaken with success determined as survival of plants for a minimum of two years. Larger-scale efforts can then be planned with greater confidence of success and return on investment.

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Bay Scallops

We note that the Report states that "successful reintroduction of bay scallops to the Lynnhaven River is highly dependent on the establishment of robust seagrass beds within the project area" (pp. 74-75) and we concur. While the bay scallop has been found to exploit habitats other than SAV beds (Carroll *et al.* 2010, Cordero *et al.* 2012, Carroll *et al.* 2013), these are not preferred habitats and are unlikely to support the Report objective of establishing a sustainable scallop population. We further note that the Report indicates that scallop restoration will not be initiated "until a minimum of one year after SAV restoration begins" (p. *v*). Given the ephemeral nature of *Ruppia maritima* and high inter-annual variability in persistence of newly established *Zostera marina* beds, we strongly recommend that bay scallop restoration not be initiated until large SAV beds dominated by eelgrass show 3-5 years of sustained presence at healthy densities. Even without the compounded risk of establishing sustainable SAV beds at a scale that can support bay scallop habitat requirements, the attempt to introduce and create a sustainable population of bay scallops carries its own inherent risks. Most notably, bay scallop introduction/restoration is a very young science in Virginia, and without large native populations from which to harvest and transplant there are significant supply issues that have not been addressed in the Report, including the acquisition and maintenance of broodstock with sufficient genetic diversity, quarantine facilities for holding spawning stocks brought from other regions (which can contain epibionts not native to Virginia), and the production facilities for producing the 100's of thousands, if not millions, of scallops that will likely be required to establish a self-sustaining population.

Wetlands Restoration

The Report's objective of restoring the function of vegetated tidal wetlands through eradication of common reed (*Phragmites australis*) and establishing vegetative diversity with plants native to Chesapeake Bay marshes is problematic and may not provide the desired return on investment. Primarily, common reed has been demonstrated to have numerous ecosystem service benefits that approach the functional levels of the tidal marsh vegetation native to Chesapeake Bay (Wainwright *et al.* 2000, Weis *et al.* 2002, Weiss and Weis 2001, Windham *et al.* 2001, 2003, Windham & Meyerson 2003, Yuhas *et al.* 2005, Hershner & Havens 2008). Therefore, it is highly likely that substrate removal will degrade, or eliminate, ecosystem services for an extended period of time, with no certainty that the replacement community will provide significantly enhanced functions. Lowering the elevation of the marsh substrate will certainly reduce the habitat suitability for common reed, but VIMS faculty and staff are aware of no evidence that suggests physical modification of the supporting substrate alone results in effective eradication, especially since the roots and rhizomes of common reed can extend meters below the soil surface (Haslam 1971). There is evidence that an introduction of sulfides (i.e. enhanced saltwater input) in conjunction with reductions in marsh elevation prohibits re-colonization by common reed, but this may be impracticable at the target sites. If removal of the road culverts responsible for limiting the tidal exchange at two of the sites would increase salinity and tidal exchange, then we recommend revisiting this option. Without an increase in salinity to complement lowering the marsh elevation, there is an increased probability that common reed will reestablish over a few growing seasons.

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The targeted sites are expected to be inundated under normal high tide conditions by the year 2040 (Berman and Berquist 2009), thus there is a high probability that marshes dominated by common reed will convert to saltmarsh cordgrass due to the respective changes in habitat suitability. An alternative strategy that recognizes and utilizes inevitable sea level rise, provides flexibility in dealing with marshes dominated by common reed, and also addresses the desire to increase the ecosystem services provided by native tidal marshes is the acquisition of upland open spaces at marsh margins to allow retreat. We recommend consideration of this strategy to replace or complement the proposed approach.

Essential Fish Habitat

The Report proposes large-scale placement of concrete structures (commonly known as "reef balls") in varying water depths to promote the establishment of reef habitat. Reef balls and other materials have been used in numerous places throughout Virginia's portion of Chesapeake Bay with the intent of providing three-dimensional substrate for oyster settlement. Varying degrees of success have been realized from these efforts. The scale of this plan element is large and the Report does not sufficiently address what communities are targeted for restoration with these structures. However, if a primary intent of reef creation is to facilitate sustainable oyster habitat and not merely to provide three-dimensional habitat for nekton, then these structures should be located in a manner that takes advantage of flow patterns that can optimize the dispersal, recruitment and interconnectivity of the reefs. The proposed placement may be sub-optimal since the selection of these sites was not guided by the hydrodynamic and water quality models that were developed specific to the Lynnhaven system. We recommend completing this exercise and adjusting the locations accordingly. Alternative structures should also be considered since reef balls were originally designed to mimic coral reef habitats and are not the most realistic mimic of temperate oyster reefs and structured habitats. Depending on the objectives of this element of the plan, there are numerous structures of various materials and designs available that can address a range of intended outcomes. Native oyster shell should also be a candidate material. We further recommend, as discussed below, that the scale and aggressiveness of this plan element be revisited and planned in an appropriate adaptive management framework incorporating a staged approach. Related to adaptive management and monitoring, the Report appears unclear regarding the success criteria for this plan element. Success criteria should be developed, and a removal plan should be incorporated into the Report in the event of failure.

Promoting Future Success

Successful establishment/enhancement/restoration requires robust supporting monitoring and an adaptive management structure committed to success. Projected annual monitoring costs presented in the Report are approximately $140,000 for the first five years, $64,000 for the next five years, and $10,000 for the next 40 years. These are dispersed amongst EFH, SAV, bay scallops, and wetland restoration sites with varying monitoring timeframes. We are unable to determine if these levels are sufficient; however, the monitoring timeframes assume an immediacy in resource establishment and function that is highly unlikely. Robust monitoring is necessary for all scales of ecosystem enhancement and restoration, especially at the large scale proposed for the Lynnhaven system. Monitoring should be designed to support an adaptive management strategy. We also are unable to determine whether or not the resources available for monitoring support the proposed approach since we do not view the proposed

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management approach as truly adaptive. The management approach described in the Report is not an iterative process that builds on the monitoring information base, but rather assesses the outcomes of the monitoring and relies on the lone strategy of moving the activities to another location in the watershed if monitoring data do not meet expectations. The aggressive approach outlined in the Report has an overall low likelihood of success. It is our collective opinion that an adaptive management strategy should be considered in which the chosen, or alternative, actions of the project are initiated on smaller scales over longer timeframes, and are either increased in stages, altered, or even abandoned based on monitoring data that address specific questions and issues.

Thank you for allowing VIMS the opportunity to provide comments. VIMS faculty and staff share in the desire to see improvement in Chesapeake Bay watersheds and offer to contribute our expertise in the Lynnhaven and other watersheds of concern as a partner with the Norfolk District Corps of Engineers.

Sincerely,

Mark Luckenbach

Dr. Mark Luckenbach
Associate Dean of Research
& Advisory Services

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Virginia Institute of Marine Science

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Virginia Institute of Marine Science

20 June 2013

Gregory C. Steele, P.E.
Chief, Planning and Policy
US Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, VA 23510-1096

Dear Mr. Steele:

This letter supplements, but does not replace, the May 20th, 2013 comments by the Virginia Institute of Marine Science (VIMS) regarding the *Lynnhaven River Basin Ecosystem Restoration Draft Feasibility Report and Integrated Environmental Assessment*.

First, I would like to thank you for the opportunity to discuss the Lynnhaven Report and our comments in greater detail with you and your staff on May 31st. The conversations were productive in helping us better understand the flexibility that you have at later stages to modify the design details and employ adaptive management. It is my hope that they were equally helpful to you and your staff in recognizing our willingness to provide technical expertise to assist you in the design and implementation of the project.

It is our opinion that if you are able to implement the SAV restoration in a manner consistent with our discussions, your likelihood of success with this phase of the project will be substantially enhanced. Specifically, we recommend (1) that site selection be driven by current water quality, depth and bottom conditions and (2) that small test plots be established initially to validate survival for a full year prior to larger scale seeding of an area. Concurrent monitoring of water quality at the test plot sites would provide valuable insights into to the conditions responsible for the success or failure of individual plots.

We stand by our previous recommendation that bay scallop restoration not proceed until eelgrass beds have persisted for a minimum of 3 years and recommend, even in that case, that serious consideration be given to the scale of the grass beds that have been established. Though we do not know the minimum grass bed size required to support a sustainable population of bay scallops, it is clear that more than a few small patches will be necessary. I reiterate our willingness to provide technical assistance with the acquisition of broodstock and the rearing of scallops once you reach that phase in the project.

As discussed in our meeting, there are alternative approaches to wetlands enhancement and diversification that are likely within your range of design options in the next phase of this process. Our wetlands scientists are willing to assist your team on this in the design and implementation phases of this element of the plan.

We do not question the technical feasibility of deploying reef balls or that oysters and other epibenthic organisms will attach to and grow on these structures. We recommend, however, that careful consideration be given to the specific ecosystem responses that are anticipated from this activity, how

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those differ from or enhance those resulting from the substantial amount of anthropogenic hard substrate already in the system, and how these specific responses will be measured.

Watershed-scale restoration and enhancement efforts are an important part of Chesapeake Bay restoration and, if designed and implemented properly, can provide real and significant benefits to the littoral marine environment and the local watershed-based community. Our previous comments address only the feasibility of the proposed technical elements and should not be interpreted as a commentary on the project's intent or concept. VIMS supports these types of focused efforts and we support the Norfolk District's desire to enhance the Lynnhaven River basin. We are well aware that this is a broadly shared desire as evidenced by the strong community support for a healthier Lynnhaven River, which ultimately is critical to project acceptance, momentum, and success.

As stated in our previous comments, we look forward to working with the Norfolk District and the City of Virginia Beach in applying the principles of sound science to this project.

Sincerely,

Mark Luckenbach

Dr. Mark Luckenbach
Associate Dean of Research
& Advisory Services

Cc: Mr. Tony Watkinson, Chief, Habitat Management, VMRC
Mr. Clay, Administrator, Environment and Sustainability Office, City of Virginia Beach

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COMMONWEALTH of VIRGINIA

Marine Resources Commission
2600 Washington Avenue
Third Floor
Newport News, Virginia 23607

Douglas W. Domenech
Secretary of Natural Resources

Jack G. Travelstead
Commissioner

May 24, 2013

Janet Cote
Ecologist
US Army Corps of Engineers
Norfolk District
Planning and Policy Branch
803 Front Street
Norfolk, VA 23510-1096

Re: Lynnhaven River Basin Ecosystem Restoration Feasibility Study

Dear Ms. Cote:

Thank you for the opportunity to comment on the Corps' study to help restore the Lynnhaven River Ecosystem within the City of Virginia Beach. As you know, in accordance with Chapter 12 of Section 28.2 of the Code of Virginia, all of the submerged bottomlands of the Lynnhaven system channelward of the mean low water mark remain the property of the Commonwealth, and therefore fall under the regulatory jurisdiction of the Virginia Marine Resources Commission (Commission). Any proposal to impact, encroach, fill, or dredge such submerged bottomlands must first garner an exemption or permit from the Commission. For every permit request the Commission reviews the proposal and attempts to identify potential benefits and detriments for the marine resource and the public utilizing and enjoying such resource. As in any application, the specific goal and purpose of the proposal must be clearly identified. When Commission permits are required, a public interest review is undertaken, including specific agency requests for comments and questions. For the purpose of this response, I would like to focus on a few of the Study's proposals which will eventually require the submittal of Joint Permit Applications and the issuance of Commission permits.

The proposal to install concrete oyster reefs and establish SAV habitat areas in various areas of the Lynnhaven system may conflict with current shellfish-lease activities, as most of the lower Lynnhaven system is currently leased for commercial shellfish production. Any such request to impact existing leases will require a notification to the record leaseholder(s), and confirmation that they agree with the proposal on their lease. Although it may be legally possible for the locality to acquire or condemn existing private leases for governmental purposes, it is unclear at this time if the City of Virginia Beach will support such initiatives for the "restorative" purposes identified in this study.

US Army Corps of Engineers
May 24, 2013
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Along with your proposed SAV habitat areas, you have proposed to introduce scallops as a new marine species in the Lynnhaven. Notwithstanding the fact that the proposed SAV must succeed and thrive for a few growing seasons before scallops can be introduced, such a species introduction may raise additional management issues. Proposed SAV areas and future scallop production, although signs of a healthy ecosystem, may further limit other existing shellfish aquaculture activities as well as public access to areas within the Lynnhaven system. The benefits and detriments of such a proposal will need to be ultimately weighed by the Commission before a permit decision can be reached. Overall, the Corps and City, as well as all participating regulatory agencies, should expect several questions and possibly even protests to components of the overall proposal. These questions and protests may come from a variety of sources such as commercial waterman, riparian property owners, waterfront businesses and contractors, and even other regulatory agencies and governmental representatives.

As is the case for any large restoration proposal, we all benefit from the involvement and recommendations provided by our scientific experts with the Virginia Institute of Marine Science (VIMS). Setting aside our specific and mandatory permit requirements for the Joint Permit Application process, we have carefully reviewed VIMS'overall comments regarding the proposed restoration efforts. We note that VIMS has pointed out several items of concern with the overall projected success of the concrete reefs, SAV, and even scallop populations. While we do not want to discourage you or the City in any way from proposing restorative initiatives, we think you should carefully consider the expert advice provided by VIMS, an institute with a long and well-documented history of scientific research within the Lynnhaven system. It also should be pointed out that quite often the Commission relies upon VIMS for advice and guidance when it comes to permitting decisions. The Corps and the City, and any other applicant for that matter, may certainly apply for any use of State-owned submerged bottomlands, however the full Commission will no doubt give great weight to the advice and guidance from VIMS.

As for the proposed wetlands restoration sites identified in the study, provided that all efforts and impacts occur on City-owned or leased wetlands, the City's Wetlands Board will not need to hear and permit the projects. You will need to work closely with the City's Wetlands Board Staff to ensure that your proposals qualify for local exemptions. We will provide oversight assistance to the City, however, they will make final decisions regarding local jurisdiction.

US Army Corps of Engineers
May 24, 2013
Page 3

Again, thank you for the opportunity to provide comments on the Corps' proposal. If you or anyone from the City has questions regarding these comments or the Commission's jurisdiction and permitting responsibilities, please feel free to contact us.

Sincerely,

Tony Watkinson
Chief, Habitat Management

TW/jdw:and
HM
cc: Jack Travelstead, Commissioner
Rob O'Reily, Chief, Fisheries Management
Clay Bernick, City of Virginia Beach
B. Kay Wilson, City of Virginia Beach
Steve McLaughlin, City of Virginia Beach
Mark Luckenbach, VIMS
Virginia Department of Health – Shellfish

Appendix G
Chesapeake Bay References
Executive Order 13508:
Chesapeake Bay Protection and Restoration

Chesapeake Bay References

Chesapeake Bay Program: http://www.chesapeakebay.net/about
The Chesapeake Bay Program is a unique regional partnership that has led and directed the restoration of the Chesapeake Bay since 1983. The Chesapeake Bay Program partners include the states of Maryland, Pennsylvania and Virginia; the District of Columbia; the Chesapeake Bay Commission, a tri-state legislative body; the Environmental Protection Agency, representing the federal government; and participating citizen advisory groups. For more, visit our overview of the Chesapeake Bay Program.

Chesapeake Bay Foundation: http://www.cbf.org/
Saving the Bay through education, advocacy, litigation, and restoration.

Chesapeake 2000, Chesapeake Bay Agreement:
http://www.epa.gov/region03/chesapeake/grants/2013Guidance/Attachment1_Chesapeake_2000_Agreement.pdf

Chesapeake Bay Protection and Restoration, Executive Order 13508:
http://executiveorder.chesapeakebay.net/default.aspx
On May 12, 2009, President Barack Obama signed an Executive Order that recognizes the Chesapeake Bay as a national treasure and calls on the federal government to lead a renewed effort to restore and protect the nation's largest estuary and its watershed. The Chesapeake Bay Protection and Restoration Executive Order established a Federal Leadership Committee that will oversee the development and coordination of reporting, data management and other activities by agencies involved in Bay restoration. The committee will be chaired by the Administrator of the Environmental Protection Agency and include senior representatives from the departments of Agriculture, Commerce, Defense, Homeland Security, Interior, Transportation and others. Full text located in this Appendix. Links to documents supporting the Executive Order are below:

Strategy for Protecting and Restoring the Chesapeake Bay Watershed:
http://executiveorder.chesapeakebay.net/file.axd?file=2010%2f5%2fChesapeake+EO+Strategy%20.pdf

2013 Action Plan: http://executiveorder.chesapeakebay.net/EO_13508_FY13_Action_Plan.pdf

2012 Annual Progress Report:
http://executiveorder.chesapeakebay.net/EO_13508_FY13_Action_Plan.pdf

THE WHITE HOUSE
Office of the Press Secretary
For Immediate Release May 12, 2009
EXECUTIVE ORDER

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CHESAPEAKE BAY PROTECTION AND RESTORATION

By the authority vested in me as President by the Constitution and the laws of the United States of America and in furtherance of the purposes of the Clean Water Act of 1972, as amended (33 U.S.C. 1251 *et seq.*), and other laws, and to protect and restore the health, heritage, natural resources, and social and economic value of the Nation's largest estuarine ecosystem and the natural sustainability of its watershed, it is hereby ordered as follows:

PART 1 - PREAMBLE

The Chesapeake Bay is a national treasure constituting the largest estuary in the United States and one of the largest and most biologically productive estuaries in the world. The Federal Government has nationally significant assets in the Chesapeake Bay and its watershed in the form of public lands, facilities, military installations, parks, forests, wildlife refuges, monuments, and museums.

Despite significant efforts by Federal, State, and local governments and other interested parties, water pollution in the Chesapeake Bay prevents the attainment of existing State water quality standards and the "fishable and swimmable" goals of the Clean Water Act. At the current level and scope of pollution control within the Chesapeake Bay's watershed, restoration of the Chesapeake Bay is not expected for many years. The pollutants that are largely responsible for pollution of the Chesapeake Bay are nutrients, in the form of nitrogen and phosphorus, and sediment. These pollutants come from many sources, including sewage treatment plants, city streets, development sites, agricultural operations, and deposition from the air onto the waters of the Chesapeake Bay and the lands of the watershed.

Restoration of the health of the Chesapeake Bay will require a renewed commitment to controlling pollution from all sources as well as protecting and restoring habitat and living resources, conserving lands, and improving management of natural resources, all of which contribute to improved water quality and ecosystem health. The Federal Government should lead this effort. Executive departments and agencies (agencies), working in collaboration, can use their expertise and resources to contribute significantly to improving the health of the Chesapeake Bay. Progress in restoring the Chesapeake Bay also will depend on the support of State and local governments, the enterprise of the private sector, and the stewardship provided to the Chesapeake Bay by all the people who make this region their home.

PART 2 - SHARED FEDERAL LEADERSHIP, PLANNING, AND ACCOUNTABILITY

Sec. 201. Federal Leadership Committee. In order to begin a new era of shared Federal leadership with respect to the protection and restoration of the Chesapeake Bay, a Federal Leadership Committee (Committee) for the Chesapeake Bay is established to oversee the development and coordination of programs and activities, including data management and reporting, of agencies participating in protection and restoration of the Chesapeake Bay. The Committee shall manage the development of strategies and program plans for the watershed and ecosystem of the Chesapeake Bay and oversee their implementation. The Committee shall be chaired by the Administrator of the Environmental Protection Agency (EPA), or the Administrator's designee, and include senior representatives of the Departments of Agriculture (USDA), Commerce (DOC), Defense (DOD), Homeland Security (DHS), the Interior (DOI), Transportation (DOT), and such other agencies as determined by the Committee. Representatives serving on the Committee shall be officers of the United States.

Sec. 202. Reports on Key Challenges to Protecting and Restoring the Chesapeake Bay.

Within 120 days from the date of this order, the agencies identified in this section as the lead agencies shall prepare and submit draft reports to the Committee making recommendations for accomplishing the following steps to protect and restore the Chesapeake Bay:
(a) define the next generation of tools and actions to restore water quality in the Chesapeake Bay and describe the changes to be made to regulations, programs, and policies to implement these actions;
(b) target resources to better protect the Chesapeake Bay and its tributary waters, including resources under the Food Security Act of 1985 as amended, the Clean Water Act, and other laws;
(c) strengthen storm water management practices at Federal facilities and on Federal lands within the Chesapeake Bay watershed and develop storm water best practices guidance;
(d) assess the impacts of a changing climate on the Chesapeake Bay and develop a strategy for adapting natural resource programs and public infrastructure to the impacts of a changing climate on water quality and living resources of the Chesapeake Bay watershed;

(e) expand public access to waters and open spaces of the Chesapeake Bay and its tributaries from Federal lands and conserve landscapes and ecosystems of the Chesapeake Bay watershed; 3
(f) strengthen scientific support for decisionmaking to restore the Chesapeake Bay and its watershed, including expanded environmental research and monitoring and observing systems; and
(g) develop focused and coordinated habitat and research activities that protect and restore living resources and water quality of the Chesapeake Bay and its watershed.
The EPA shall be the lead agency for subsection (a) of this section and the development of the storm water best practices guide under subsection (c). The USDA shall be the lead agency for subsection (b). The DOD shall lead on storm water management practices at Federal facilities and on Federal lands under subsection (c). The DOI and the DOC shall share the lead on subsections (d), (f), and (g), and the DOI shall be lead on subsection (e). The lead agencies shall provide final reports to the Committee within 180 days of the date of this order.

Sec. 203. Strategy for Protecting and Restoring the Chesapeake Bay.

The Committee shall prepare and publish a strategy for coordinated implementation of existing programs and projects to guide efforts to protect and restore the Chesapeake Bay. The strategy shall, to the extent permitted by law:
(a) define environmental goals for the Chesapeake Bay and describe milestones for making progress toward attainment of these goals;
(b) identify key measureable indicators of environmental condition and changes that are critical to effective Federal leadership;
(c) describe the specific programs and strategies to be implemented, including the programs and strategies described in draft reports developed under section 202 of this order;
(d) identify the mechanisms that will assure that governmental and other activities, including data collection and distribution, are coordinated and effective, relying on existing mechanisms where appropriate; and
(e) describe a process for the implementation of adaptive management principles, including a periodic evaluation of protection and restoration activities.
The Committee shall review the draft reports submitted by lead agencies under section 202 of this order and, in consultation with relevant State agencies, suggest appropriate revisions to the agency that provided the draft report. It shall then integrate these reports into a coordinated strategy for restoration and protection of the Chesapeake Bay consistent with the requirements of this order. Together with the final reports prepared by the lead agencies, the draft strategy shall be published for public review and comment within 180 days of the date of this order and a final strategy shall be published within 1 year. To the extent

practicable and authorized under their existing authorities, agencies may begin implementing core elements of restoration and protection programs and strategies,
in consultation with the Committee, as soon as possible and prior to release of a final strategy.

Sec. 204. Collaboration with State Partners. In preparing the reports under section 202 and the strategy under section 203, the lead agencies and the Committee shall consult extensively with the States of Virginia, Maryland, Pennsylvania, West Virginia, New York, and Delaware and the District of Columbia. The goal of this consultation is to ensure that Federal actions to protect and restore the Chesapeake Bay are closely coordinated with actions by State and local agencies in the watershed and that the resources, authorities, and expertise of Federal, State, and local agencies are used as efficiently as possible for the benefit of the Chesapeake Bay's water quality and ecosystem and habitat health and viability.

Sec. 205. Annual Action Plan and Progress Report. Beginning in 2010, the Committee shall publish an annual Chesapeake Bay Action Plan (Action Plan) describing how Federal funding proposed in the President's Budget will be used to protect and restore the Chesapeake Bay during the upcoming fiscal year. This plan will be accompanied by an Annual Progress Report reviewing indicators of environmental conditions in the Chesapeake Bay, assessing implementation of the Action Plan during the preceding fiscal year, and recommending steps to improve progress in restoring and protecting the Chesapeake Bay. The Committee shall consult with stakeholders (including relevant State agencies) and members of the public in developing the Action Plan and Annual Progress Report.

Sec. 206. Strengthen Accountability. The Committee, in collaboration with State agencies, shall ensure that an independent evaluator periodically reports to the Committee on progress toward meeting the goals of this order. The Committee shall ensure that all program evaluation reports, including data on practice or system implementation and maintenance funded through agency programs, as appropriate, are made available to the public by posting on a website maintained by the Chair of the Committee.

PART 3 - RESTORE CHESAPEAKE BAY WATER QUALITY

Sec. 301. Water Pollution Control Strategies. In preparing the report required by subsection 202(a) of this order, the Administrator of the EPA (Administrator) shall, after consulting with appropriate State agencies, examine how to make full use of its authorities under the Clean Water Act to protect and restore the Chesapeake Bay and its tributary waters and, as appropriate,

shall consider revising any guidance and regulations. The Administrator shall identify pollution control strategies and actions authorized by the EPA's existing authorities to restore the Chesapeake Bay that:
(a) establish a clear path to meeting, as expeditiously as practicable, water quality and environmental restoration goals for the Chesapeake Bay;
(b) are based on sound science and reflect adaptive management principles;
(c) are performance oriented and publicly accountable;
(d) apply innovative and cost-effective pollution control measures;
(e) can be replicated in efforts to protect other bodies of water, where appropriate; and
(f) build on the strengths and expertise of Federal, State, and local governments, the private sector, and citizen organizations.
Sec. 302. Elements of EPA Reports. The strategies and actions identified by the Administrator of the EPA in preparing the report under subsection 202(a) shall include, to the extent permitted by law:
(a) using Clean Water Act tools, including strengthening existing permit programs and extending coverage where appropriate;
(b) establishing new, minimum standards of performance where appropriate, including:
(i) establishing a schedule for the implementation of key actions in cooperation with States, local governments, and others;
(ii) constructing watershed-based frameworks that assign pollution reduction responsibilities to pollution sources and maximize the reliability and cost-effectiveness of pollution reduction programs; and
(iii) implementing a compliance and enforcement strategy.

PART 4 - AGRICULTURAL PRACTICES TO PROTECT THE CHESAPEAKE BAY

Sec. 401. In developing recommendations for focusing resources to protect the Chesapeake Bay in the report required by subsection 202(b) of this order, the Secretary of Agriculture shall, as appropriate, concentrate the USDA's working lands and land retirement programs within priority watersheds in counties in the Chesapeake Bay watershed. These programs should apply priority conservation practices that most efficiently reduce nutrient and sediment loads to the Chesapeake Bay, as identified by USDA and EPA data and scientific analysis. The Secretary of Agriculture shall work with State agriculture and conservation agencies in developing the report.

PART 5 - REDUCE WATER POLLUTION FROM FEDERAL LANDS AND FACILITIES

Sec. 501. Agencies with land, facilities, or installation management responsibilities affecting ten or more acres within the

watershed of the Chesapeake Bay shall, as expeditiously as practicable and to the extent permitted by law, implement land management practices to protect the Chesapeake Bay and its more
tributary waters consistent with the report required by section 202 of this order and as described in guidance published by the EPA under section 502.

Sec. 502. The Administrator of the EPA shall, within 1 year of the date of this order and after consulting with the Committee and providing for public review and comment, publish guidance for Federal land management in the Chesapeake Bay watershed describing proven, cost-effective tools and practices that reduce water pollution, including practices that are available for use by Federal agencies.

PART 6 - PROTECT CHESAPEAKE BAY AS THE CLIMATE CHANGES

Sec. 601. The Secretaries of Commerce and the Interior shall, to the extent permitted by law, organize and conduct research and scientific assessments to support development of the strategy to adapt to climate change impacts on the Chesapeake Bay watershed as required in section 202 of this order and to evaluate the impacts of climate change on the Chesapeake Bay in future years. Such research should include assessment of:
(a) the impact of sea level rise on the aquatic ecosystem of the Chesapeake Bay, including nutrient and sediment load contributions from stream banks and shorelines;
(b) the impacts of increasing temperature, acidity, and salinity levels of waters in the Chesapeake Bay;
(c) the impacts of changing rainfall levels and changes in rainfall intensity on water quality and aquatic life;
(d) potential impacts of climate change on fish, wildlife, and their habitats in the Chesapeake Bay and its watershed; and
(e) potential impacts of more severe storms on Chesapeake Bay resources.

PART 7 - EXPAND PUBLIC ACCESS TO THE CHESAPEAKE BAY AND CONSERVE LANDSCAPES AND ECOSYSTEMS

Sec. 701. (a) Agencies participating in the Committee shall assist the Secretary of the Interior in development of the report addressing expanded public access to the waters of the Chesapeake Bay and conservation of landscapes and ecosystems required in subsection 202(e) of this order by providing to the Secretary:
(i) a list and description of existing sites on agency lands and facilities where public access to the Chesapeake Bay or its tributary waters is offered;

(ii) a description of options for expanding public access at these agency sites;
(iii) a description of agency sites where new opportunities for public access might be provided;
(iv) a description of safety and national security issues related to expanded public access to Department of Defense installations; 7
(v) a description of landscapes and ecosystems in the Chesapeake Bay watershed that merit recognition for their historical, cultural, ecological, or scientific values; and
(vi) options for conserving these landscapes and ecosystems.
(b) In developing the report addressing expanded public access on agency lands to the waters of the Chesapeake Bay and options for conserving landscapes and ecosystems in the Chesapeake Bay, as required in subsection 202(e) of this order, the Secretary of the Interior shall coordinate any recommendations with State and local agencies in the watershed and programs such as the Captain John Smith Chesapeake National Historic Trail, the Chesapeake Bay Gateways and Watertrails Network, and the Star-Spangled Banner National Historic Trail.

PART 8 - MONITORING AND DECISION SUPPORT FOR ECOSYSTEM MANAGEMENT

Sec. 801. The Secretaries of Commerce and the Interior shall, to the extent permitted by law, organize and conduct their monitoring, research, and scientific assessments to support decisionmaking for the Chesapeake Bay ecosystem and to develop the report addressing strengthening environmental monitoring of the Chesapeake Bay and its watershed required in section 202 of this order. This report will assess existing monitoring programs and gaps in data collection, and shall also include the following topics:
(a) the health of fish and wildlife in the Chesapeake Bay watershed;
(b) factors affecting changes in water quality and habitat conditions; and
(c) using adaptive management to plan, monitor, evaluate, and adjust environmental management actions.

PART 9 - LIVING RESOURCES PROTECTION AND RESTORATION

Sec. 901. The Secretaries of Commerce and the Interior shall, to the extent permitted by law, identify and prioritize critical living resources of the Chesapeake Bay and its watershed, conduct collaborative research and habitat protection activities that address expected outcomes for these species, and develop a report addressing these topics as required in section 202 of this order. The Secretaries of Commerce and the Interior shall coordinate agency activities related to living resources in estuarine waters to ensure maximum benefit to the Chesapeake Bay resources.

PART 10 - EXCEPTIONS

Sec. 1001. The heads of agencies may authorize exceptions to this order, in the following circumstances:
(a) during time of war or national emergency; 8
(b) when necessary for reasons of national security;
(c) during emergencies posing an unacceptable threat to human health or safety or to the marine environment and admitting of no other feasible solution; or
(d) in any case that constitutes a danger to human life or a real threat to vessels, aircraft, platforms, or other man-made structures at sea, such as cases of *force majeure* caused by stress of weather or other act of God.

PART 11 - GENERAL PROVISIONS

Sec. 1101. (a) Nothing in this order shall be construed to impair or otherwise affect:
(i) authority granted by law to a department, agency, or the head thereof; or
(ii) functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.
(b) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.
(c) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity, by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

BARACK OBAMA
THE WHITE HOUSE,
May 12, 2009.
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